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Aeronautical Engineering REVIEW

INSTITUTE OF THE AERONAUTICAL SCIENCES
1932 25th ANNIVERSARY 1957

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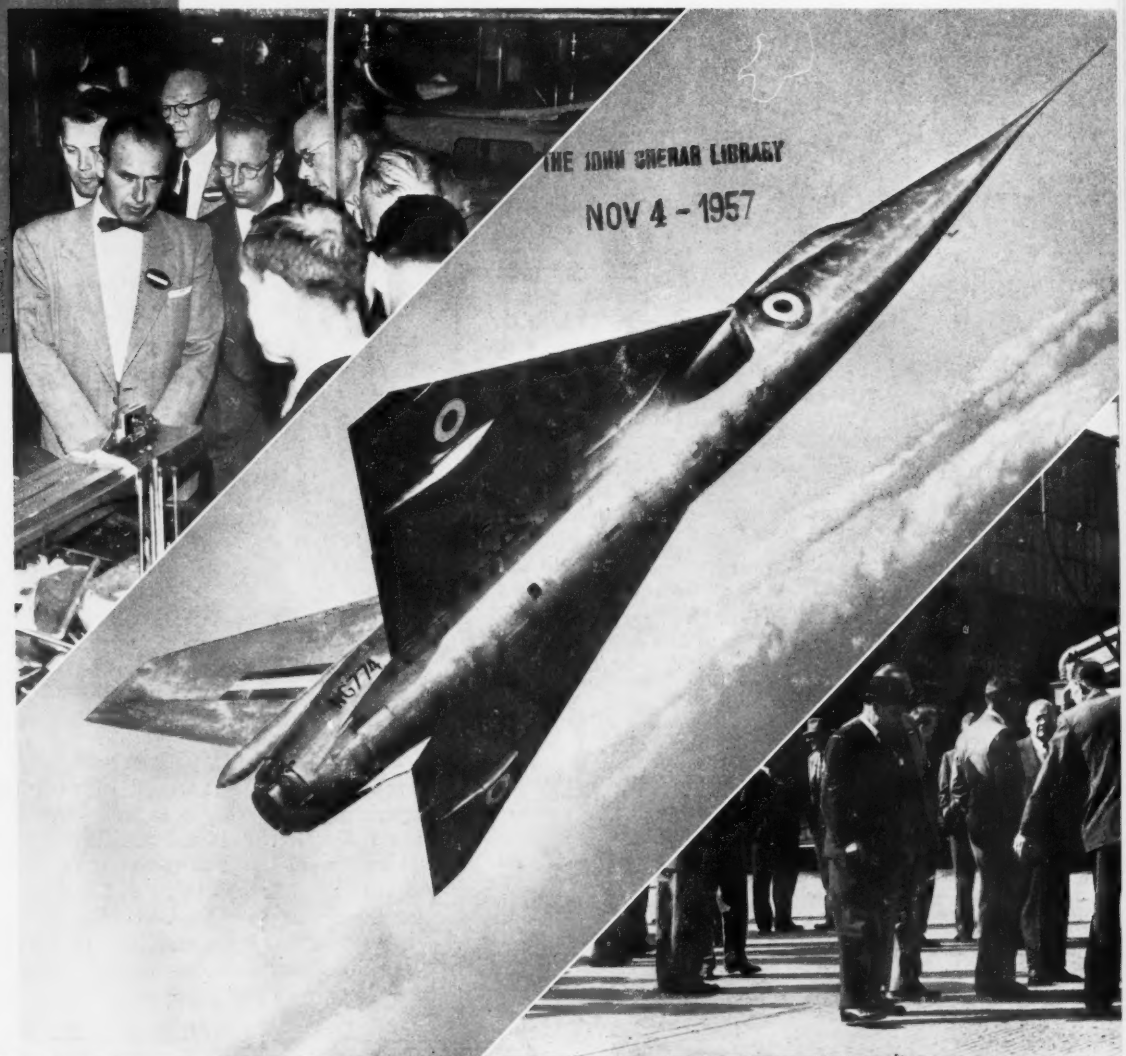

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research • design • construction • testing • operation

Sixth Anglo-American Conference

In Retrospect . . . an editorial

November, 1957

cooling avionic systems

During World War II, Eastern Industries pioneered cooling systems for aircraft electronic systems. Now, thousands of installations later, and as the leader in this challenging field, Eastern is still pioneering.

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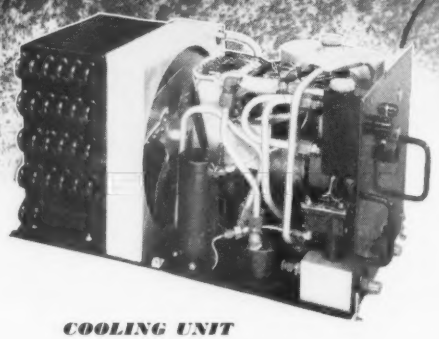
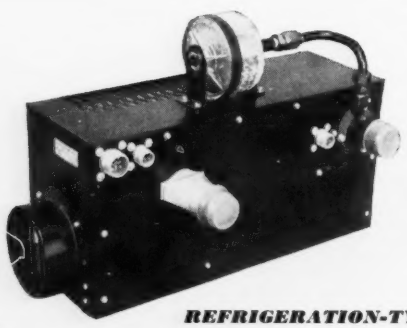


COOLING UNIT



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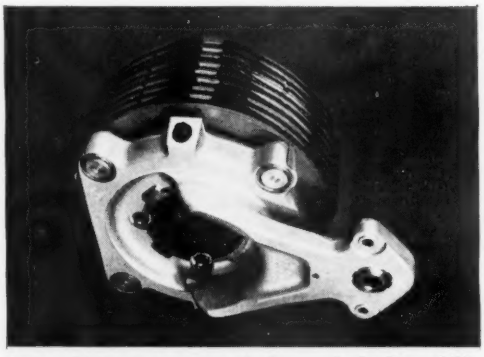

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Aeronautical Engineering Review

Vol. 16—No. 11 November, 1957

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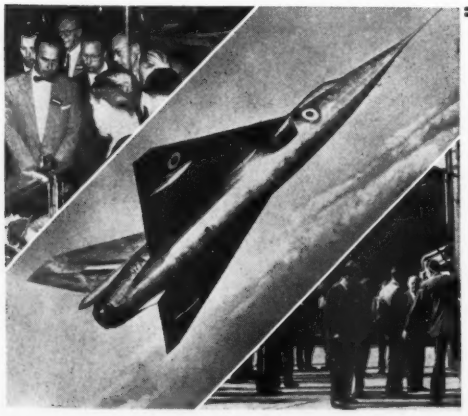

Cover—The Sixth Anglo-American Conference, IAS-RAeS, was held in London and Folkestone, Great Britain, September 1–15, 1957. British aircraft, including the Fairey Delta 2 pictured, were viewed by delegates at the SBAC Flying Display at Farnborough. For a report on the Conference, see the Editorial, pp. 30–33.

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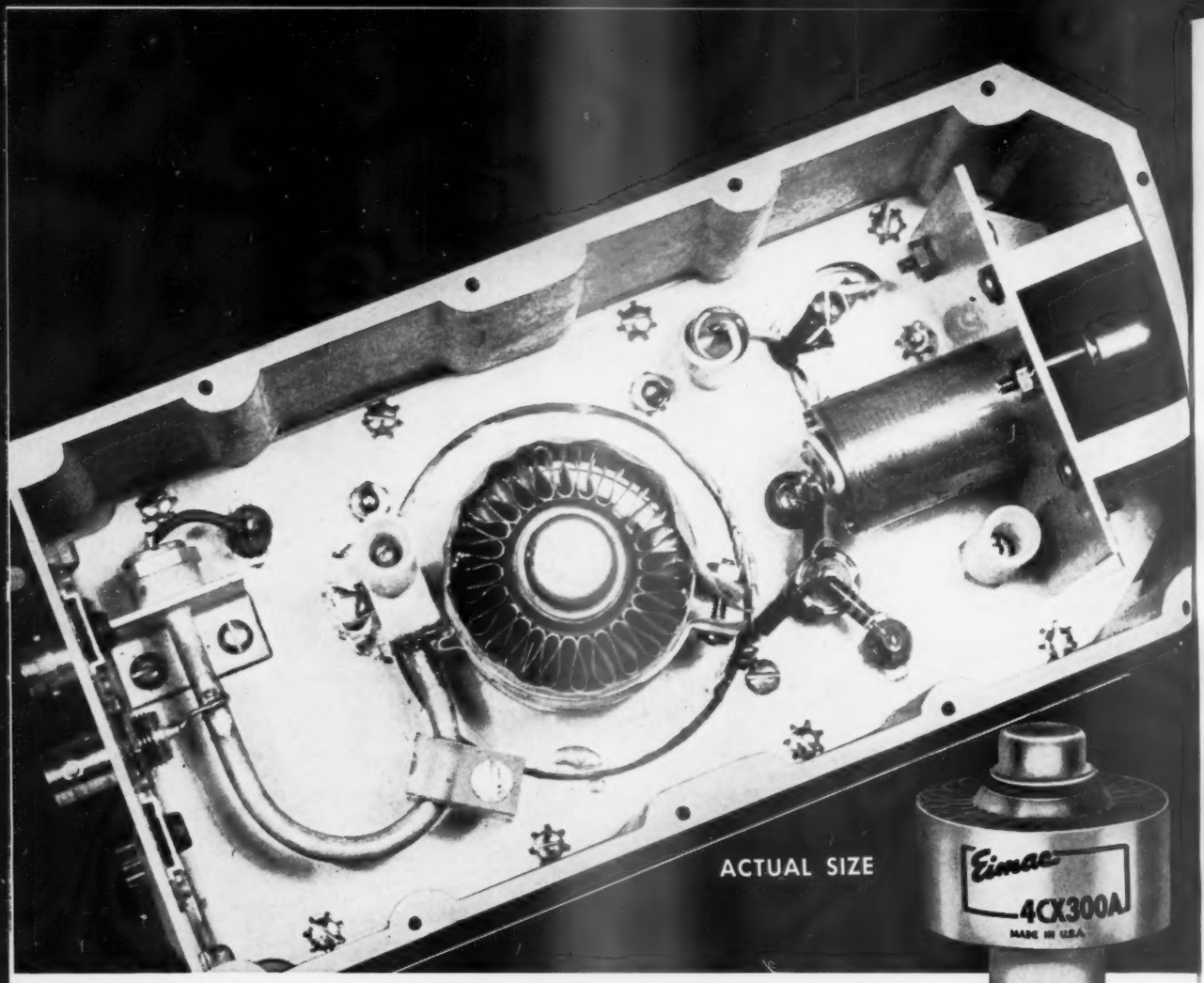

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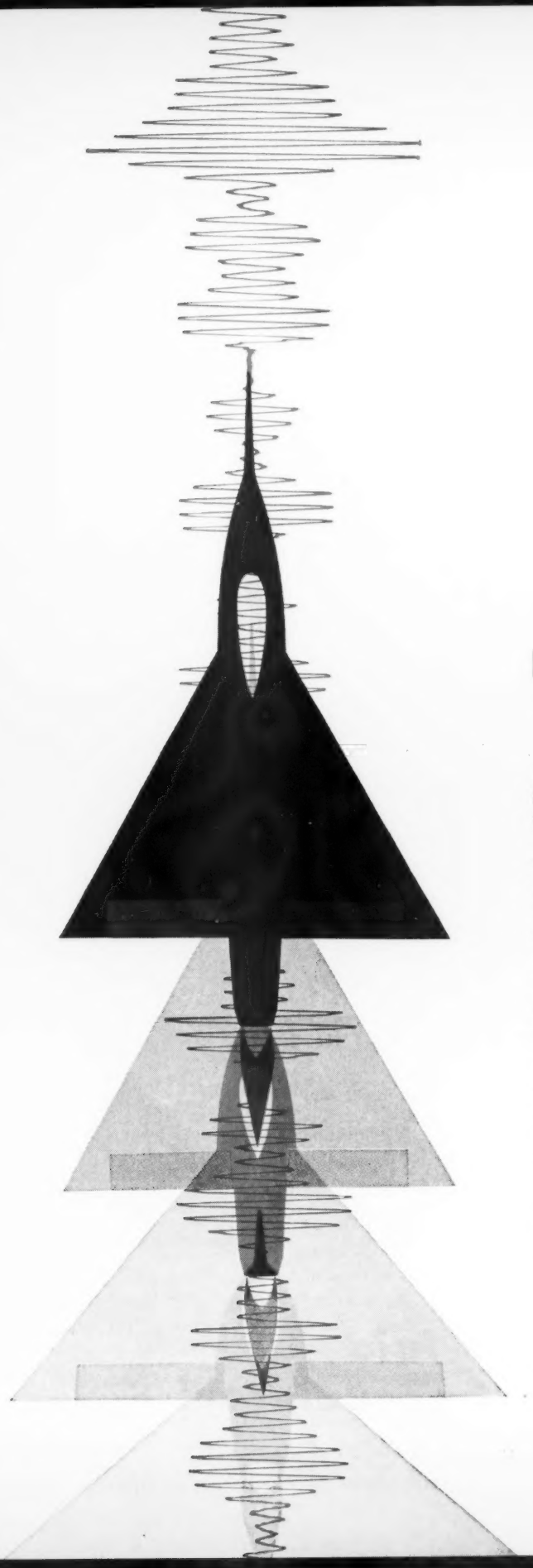

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Large new electric furnaces—the only ones of their type—were designed by Solar to braze the sandwich structures. In addition to stainless steel, various high alloys are used for the honeycomb cores, and research in the use of other metals is in progress. For more than a decade Solar has placed special emphasis on guided missile technology—developing new metalworking techniques for the missile age. Solar's versatile missile team is available *now!* For more information write to Missile Engineering, Dept. D-97, Solar Aircraft Company, San Diego 12, California. *Designers, developers and manufacturers of gas turbine engines, expansion joints and aircraft engine, airframe and missile components.*

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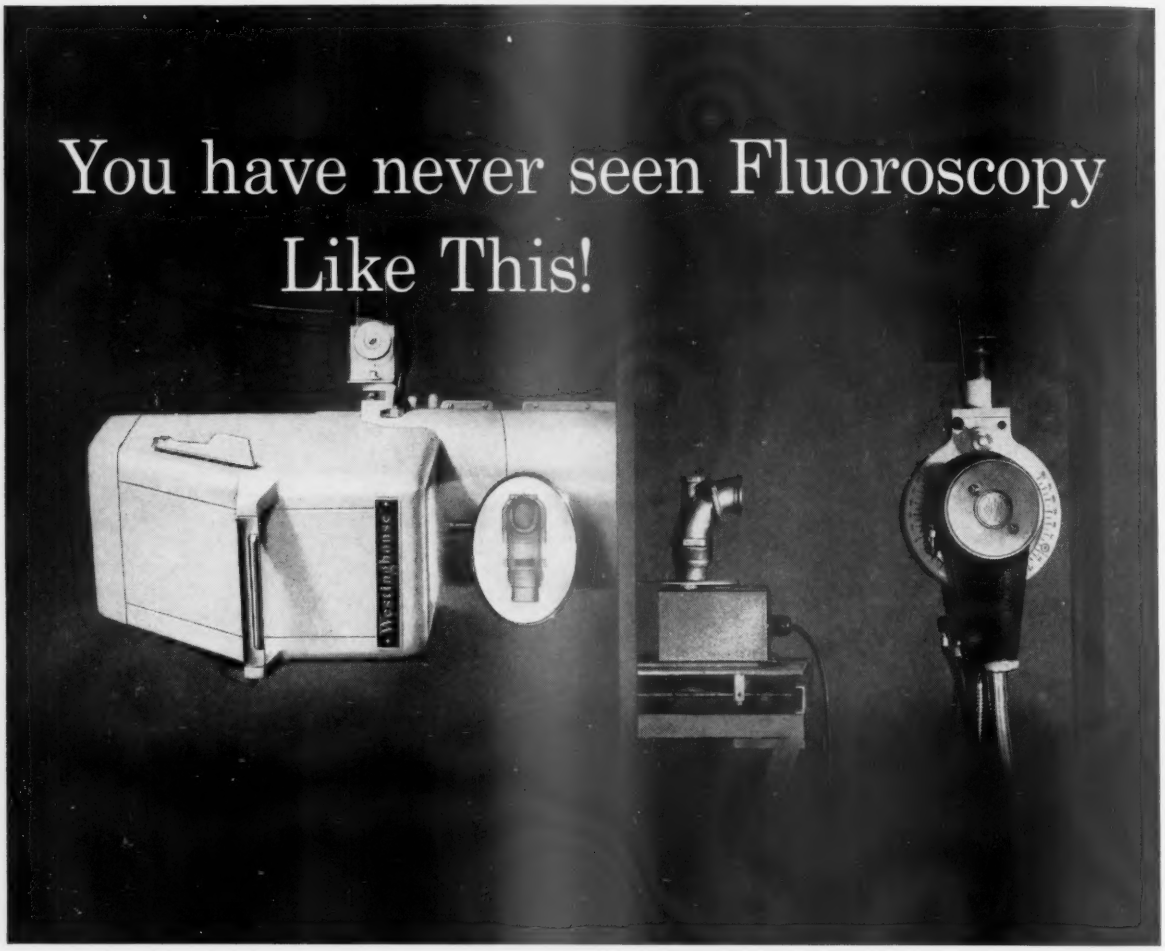

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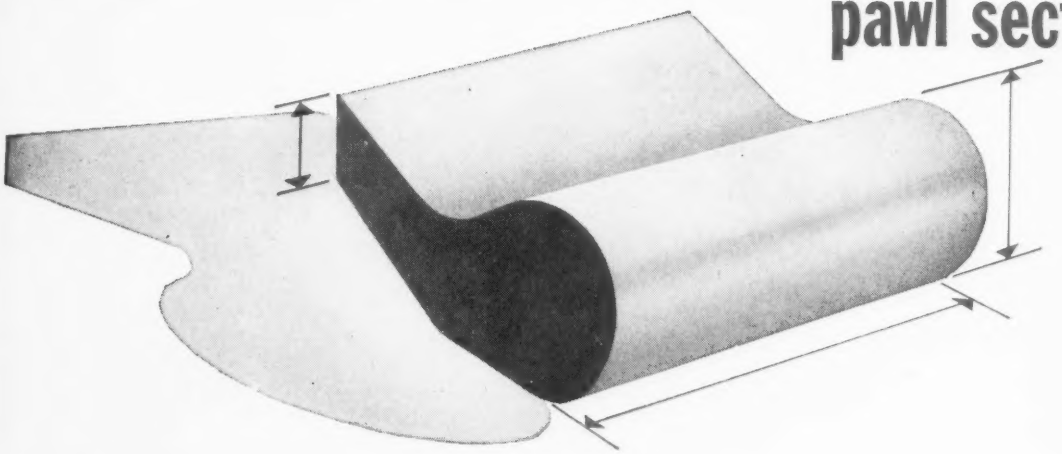

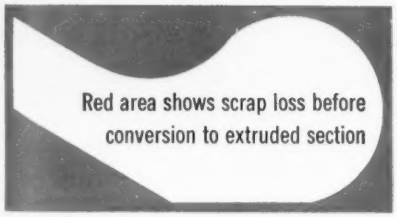

This pawl was previously milled from a ¾" x 1½" hot rolled oil hardening tool steel. Conversion to a cold drawn extruded section cut cost from 45¢ to 22¢ per part.

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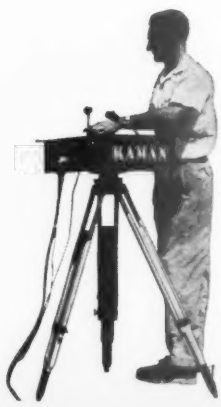

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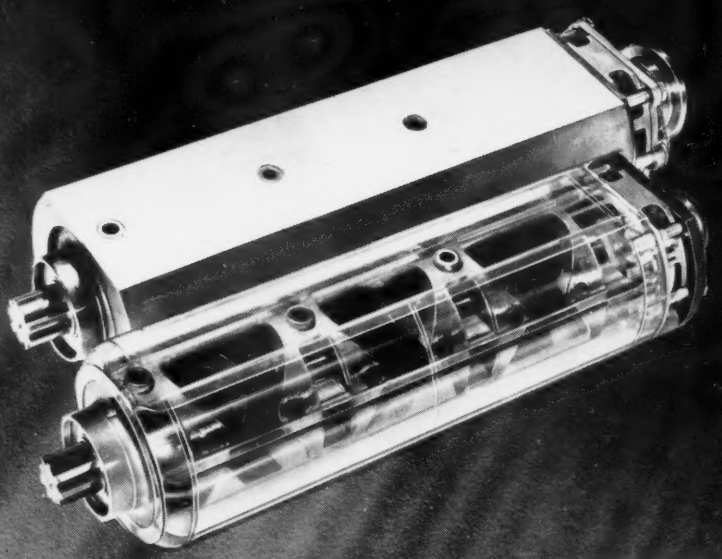

AiResearch Cam-Piston Air Motors function with complete reliability at extreme temperatures—require no conventional lubrication or cooling

SPECIFICATIONS

Model Numbers	CM-710 *(illustrated)	CM-350	CM-160
Total Length (in.)	13.3	11.8	9.7
Min. Height (in.)	3.1	2.9	2.5
Max. Dia. Envelope (in.)	4.0	3.2	2.5
Weight (lb.)	22	15.5	7.5
Output at 200 psig supply pressure and 1200 rpm (hp)	18.5	9.1	4.2
Starting Torque at 200 psig supply pressure (inch-pounds)	1800	890	400

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Using bleed air as a source of energy, the output of the air motor is almost linear with inlet pressure, allowing maximum efficiency through a wide range of operating conditions. High horsepower and torque to weight ratios are obtained by displacement volume per revolution exceeding the overall volume of the motor.

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Afterburner Cooling Assembly Gangs Straight Wall Tubing For High Strength, Light Weight

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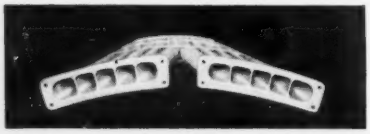
The space envelope was shallow and wide and over six feet long. The assembly was required to be tested at 28 psig with collapsing pressure of −2.5 psig and at a temperature of 250° F.

Flexonics answered the need by



End view of afterburner cooling assembly. Note rectangular shape of ends.

forming standard High Strength welded tubing into a gang. Ends of the tubes were formed to a rectangular shape to adapt them to the required end fittings. The tubes are held together with welded bands as the illustration of the unit shows. Tabs are provided for mounting in the airframe.

Tubing used in the assembly is 1.625" O.D. by .011" wall thickness. Type 321 High Strength stainless steel is used, with ultimate of 100,000 psi.

Facilities are the Key Factor

In the engineering, fabrication and proving of assemblies such as this, facilities are all important. As the pioneer and leading manufacturer of light weight corrosion resistant flexible assemblies and ducting, Flexonics Corporation has facilities second to none.

The engineering skill of Flexonics Corporation is proved by the scores of developments already made ranging from single flex connectors to entire aircraft ducting systems.

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The ability to prove assemblies before their installation in aircraft and engines is assured by the extensive Flexonics laboratories capable of the most advanced testing procedures.

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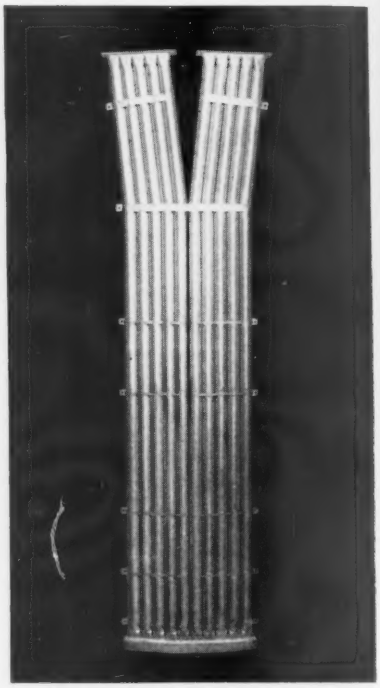
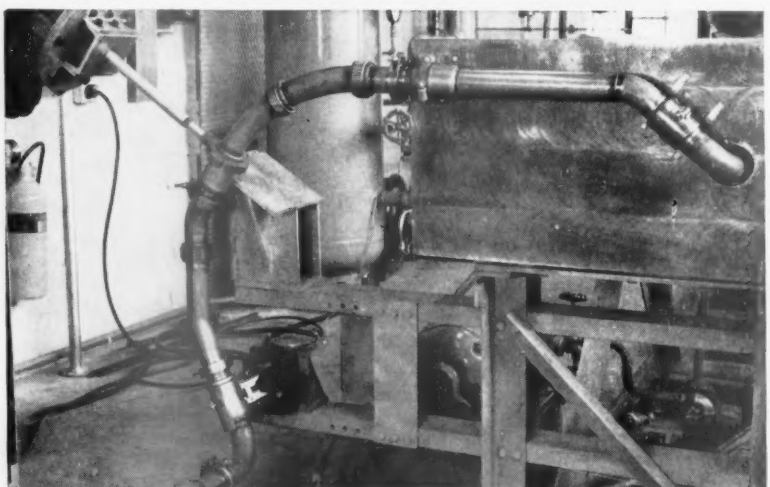
Whenever you have a problem involving aircraft plumbing, take advantage of the know-how and facilities of Flexonics Corporation. For specific recommendations send an outline of your requirements.

For help right at your desk, write for information on how qualified persons can secure copies of the new Flexonics Engineering Manual.



Complete afterburner cooling assembly. Note use of straps to gang the tubing.



Ducting system test in the Flexonics labs. Shown is a portion of vibration and flow under pressure tests of assemblies in a bleed air system for a current fighter aircraft.

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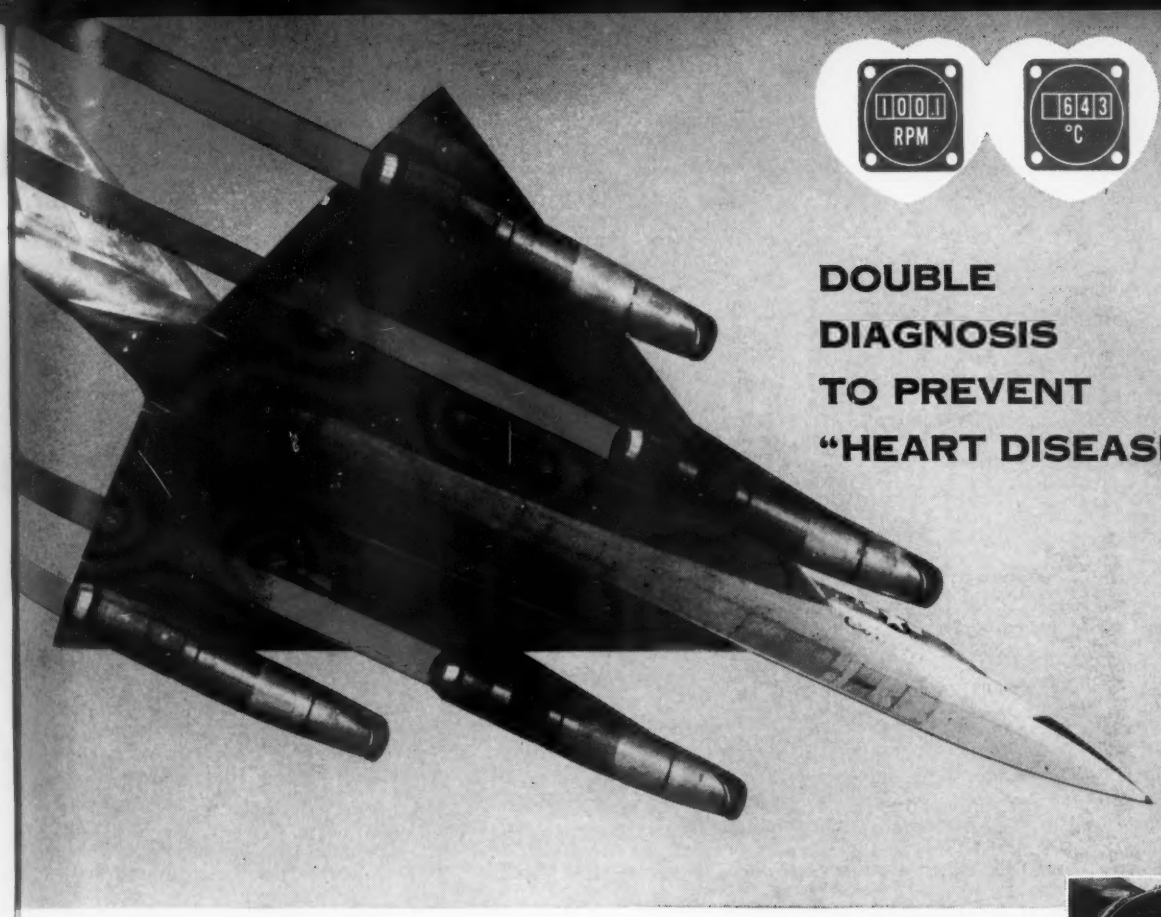

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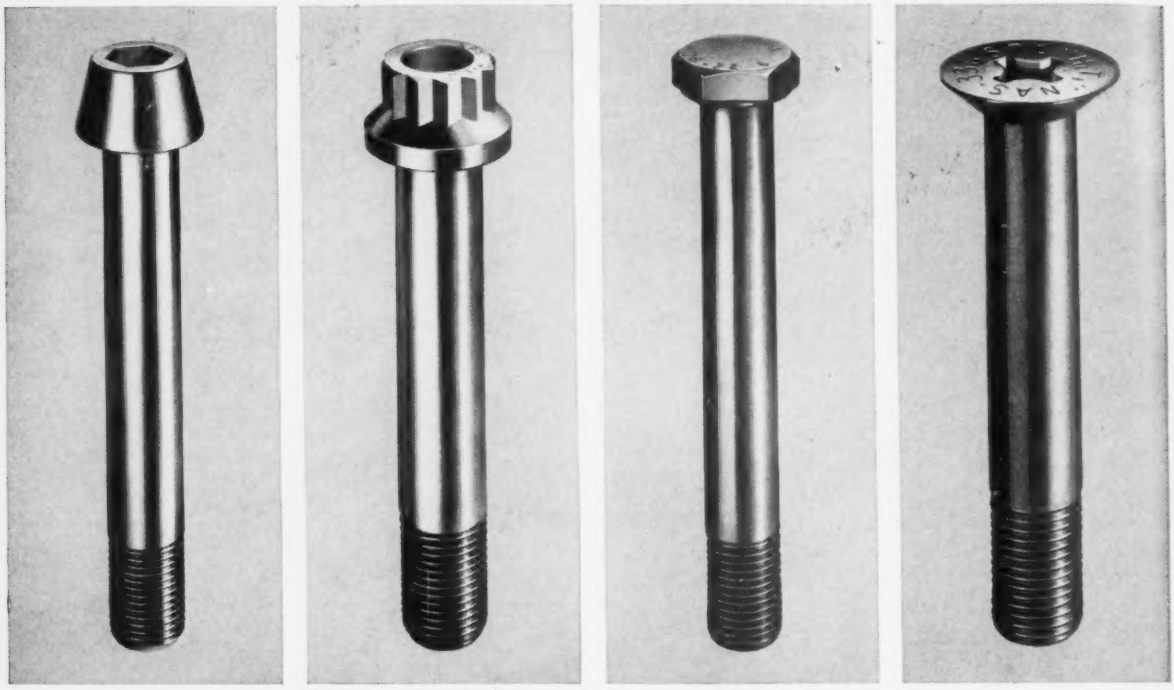
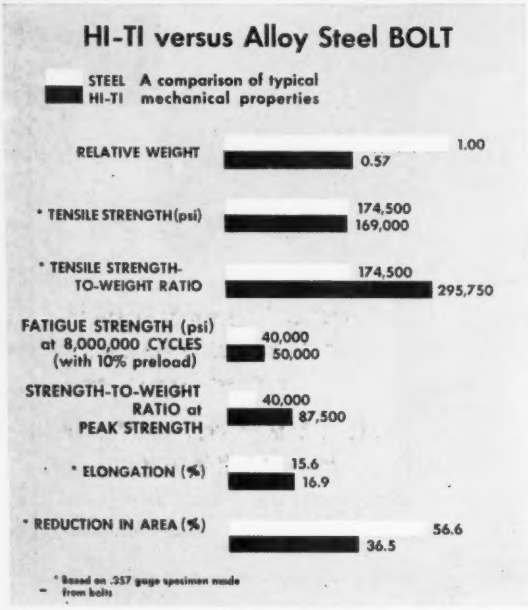


SPS Hi-Ti titanium aircraft bolts are regularly manufactured in four standard configurations: internal wrenching tension bolts, 12-point external wrenching tension bolts, hexagon head external wrenching shear bolts, and flush head internal wrenching shear bolts. Weighing 43% less than steel bolts of equivalent dimensions, they can save you as much as 1000 lb. per airframe—with no loss in strength.

SPS Hi-Ti titanium bolts help you build lighter airframes without sacrificing strength



Hi-Ti vs. alloy steel. Tensile, elongation and reduction area properties are based on the performance of bolt gage specimens. Endurance limit was determined by subjecting bolts to tension load alternating between maximum and 10% preload for a total of 8,000,000 cycles without inducing failure. Significant comparison is the strength-to-weight ratio at endurance limit.

SPS Hi-Ti titanium bolts help you solve the problem of reducing airframe weight without compromising strength. They weigh 43% less than alloy steel bolts of the same size. One lb. of them can do the work of 1¾ lb. of steel bolts. Yet in tensile-strength-to-weight ratio and fatigue resistance, they outperform steel.

Once considered a laboratory curiosity, titanium bolts have for some time been standard production items at SPS. Hi-Ti bolts are found in many advanced design operational aircraft. This is because SPS—producer of the first successful titanium aircraft bolt—invested over $500,000 and several years of high priority research in learning how to deal with this promising but sensitive metal. Today SPS has the most extensive facilities in the industry for the production and testing of titanium fasteners. As a result, we can give you both the technical assistance and the delivery you need to utilize fully the advantages of titanium bolts in your current airframe projects.

For more information on Hi-Ti titanium aircraft bolts, write Aircraft Products Division, STANDARD PRESSED STEEL Co., Jenkintown 58, Pa.

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RCA-2N384 . . . up to 250 Mc as rf oscillator; 100-Mc alpha-cutoff frequency.
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For superior-quality semiconductor devices, your best choice is always RCA. For sales information on these and other RCA TRANSISTORS, contact the RCA field Office nearest you. For technical data on specific RCA "Drift" transistor types, write RCA Commercial Engineering, Sec. K-87-NN, Somerville, N. J.

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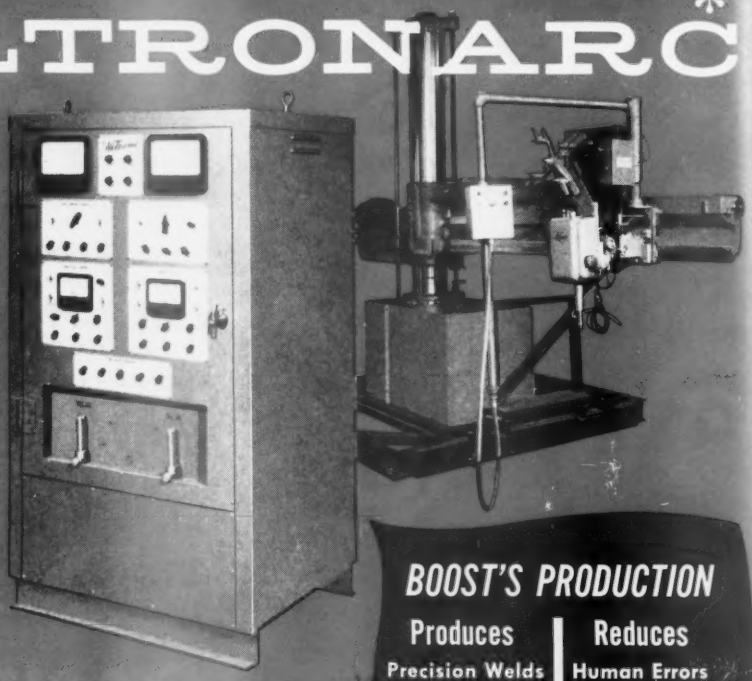

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IAS News Notes

November 1957

W. STUART SYMINGTON, Senator from Missouri and former Secretary of the Air Force (1947-50), will be the Principal Speaker at the Institute's 26th Annual Meeting Honors Night Dinner - at the Sheraton-Astor Hotel, Tuesday, January 28. Plans for the meeting call for sessions on missiles, satellites and gravity. A story on how the meeting is shaping up will appear in next month's Review.

A HANDBOOK FOR CORPORATE MEMBERS, designed to provide source information for their educational aid programs, is being compiled by the IAS Engineering Career Development Committee with publication scheduled for this month. Information for development and improvement of these programs will cover background data, youth motivation, aid at the primary and secondary school level, and aid at the college and university level.

THE DECEMBER REVIEW will contain an Index to Volume 16, covering issues from January to December, 1957. All technical articles, Institute news, editorials, and necrology for the year will be listed. Articles will be indexed according to aeronautical subject in one section, and according to author in another.

THE INSTITUTE WAS SADDENED to hear of the death of Harold Gatty (AF), who flew around the world with Wiley Post in 1931, and Commander Jack J. Tomamichel (M), who became a Navy pilot in 1935.

* * * * * *

NATIONAL MEETINGS CALENDAR

Nov. 7-8	Weapons System Management (National Midwestern Meeting.) Statler-Hilton Hotel, Dallas, Texas.
Dec. 17	Wright Brothers Lecture, Natural History Building Auditorium, Smithsonian Institution, Washington, D. C. "Hypersonic Flight and the Re-Entry Problem" by H. Julian Allen.
1958	
Jan. 27-30	Twenty-Sixth Annual Meeting, Sheraton-Astor Hotel, New York.
Mar. 13-14	Flight Propulsion Meeting (Classified), Hotel Carter, Cleveland.
May 12-14	National Midwestern Meeting on Guided Missiles, Hotel Chase, St. Louis, Missouri.
July 8-11	National Summer Meeting, Los Angeles, California
Sept. 8-13	First International Congress, International Council of the Aeronautical Sciences, Palace Hotel, Madrid, Spain.

* * * * * *

JOINT MEETINGS CALENDAR

Mar. 17-21	1958 Nuclear Congress, International Amphitheatre, Chicago. Coordinated by Engineers Joint Council.
June 2-4	National Telemetering Conference, Lord Baltimore Hotel, Baltimore, Maryland. Sponsored by IAS, ARS, ISA and AIEE.
June 19-21	1958 Heat Transfer and Fluid Mechanics Institute, University of California, Berkeley. Cosponsored by IAS.

* * * * * *

SECTION MEETINGS CALENDAR

Nov. 5	Indianapolis Section: Specialist Meeting, Union Building, Purdue University, 7 p.m. "The B-58" by Kent Campbell.
Nov. 6	Philadelphia Section: Joint Dinner Meeting with Franklin Institute, at the Institute. (Social hour at 6, dinner at 7.) "Approaches to Scientific Planning" by Felix A. Kalinski.
Nov. 12	Los Angeles Section: Specialist Meeting, IAS Building, 7:30 p.m. "Prediction of Transient Performance of Diffuser-Engine Systems" by Alan C. Brown.
Nov. 12	Tulsa Section: Dinner Meeting, Western Village. (Social hour at 6:15, dinner at 7.) "Human Factors in Space Flight" by E.B. Konecci.
Nov. 12	Washington Section: Dinner Meeting, Occidental Restaurant. (Social hour at 6, dinner at 6:45.) "Turbine Transports in Civil Operations" by James Pyle.
Nov. 13	Texas Section: Specialist Meeting, Arlington State College, 8 p.m. "IGY and Vanguard" by J. Wallace Joyce.
Nov. 14	Baltimore Section: Specialist Meeting, Westinghouse Air Arm facility, Friendship Airport, 8 p.m. "Aircraft Nuclear Propulsion" by William C. Cooley.
Nov. 18	Cleveland-Akron Section: Specialist Meeting, Akron. "Army-Navy Aircraft Instrumentation Program" by Commander G. W. Hoover, USN.
Nov. 19	Kansas City Section: Specialist Meeting, American Legion Building. "Boundary-Layer Control for Short Takeoff and Landing" by Harry C. Higgins.
Nov. 20	Chicago Section: Joint Dinner Meeting with IIT-ARF Mechanics Colloquium, Illinois Inst. of Technology, 6:30 p.m. "The Vanguard Earth Satellite Program" by Joseph W. Siry.
Nov. 21	Los Angeles Section: Dinner Meeting, IAS Building. (Social hour at 6, dinner at 7.) "Report on 1957 Farnborough Show" by W. E. Gasich. (Followed by panel discussion.)
Nov. 22	Los Angeles Section: Field Trip, Kaiser Steel, Fontana, Calif. Supper at 6:30, tour at 7.
Nov. 26	Los Angeles Section: Specialist Meeting, IAS Building, 7:30 p.m. "Aerodynamic Characteristics of Low-Aspect Ratio Dart Configurations" by J. W. Hindes.

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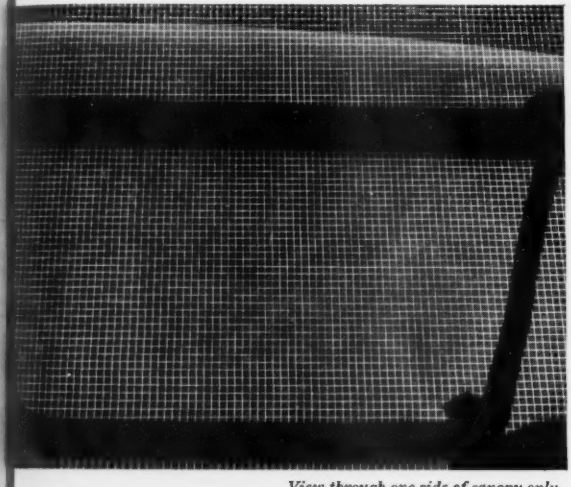
Republic F-105 canopy in front of standard test acceptance grid. Any defect in optics would result in distortion of the grid lines. Note that the Swedlow stretched acrylic Republic F-105 canopy, in a compound contour shape is virtually distortion-free.

Above: View through two sides of canopy.

NOW! SWEDLOW "STRETCHED ACRYLICS" PROVIDE GOOD OPTICS ON REPUBLIC F-105



View through one side of canopy only.

Now... on a "production basis"... aircraft canopies and windshields in compound contours are being fabricated of Swedlow stretched acrylic materials... with good optics.

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Stretching of acrylics has been a Swedlow-sponsored development over the last few years. The process involves the *molecular rearrangement* of acrylic sheeting by *appreciable* mechanical stretching.

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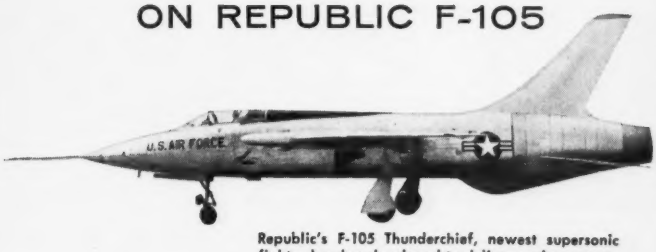

Republic's F-105 Thunderchief, newest supersonic fighter-bomber developed to deliver nuclear weapons and heavier loads of conventional bombs and rockets at extremely high speeds over long ranges, feature Swedlow-produced stretched acrylic canopies and windshields.

The F-105 encompasses such outstanding design features as the long, cylindrical fuselage, the short, very thin swept-back wings, the needle nose, and the ventral fin on the bottom of the aft fuselage near the tail. Design based on Area Rule. Wing span, over 30 ft. Length, over 60 ft. Powered by Pratt & Whitney J-75, 15,000 lb-thrust class, turbo-jet engine plus afterburner. Speed—supersonic.

Careful, technically accurate efforts go into the fabrication of each Swedlow stretched acrylic part. Republic F-105 canopy being fabricated in Swedlow plant.

Windshield on Republic's F-105, as on many other fighters and bombers, is also of Swedlow stretched acrylic... produced on a "production basis"... with good optics and contour.

Los Angeles, California

Youngstown, Ohio

Please refer to Dept. 13

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Behind the leadership at Rohr is a large company of proven skill . . . a company of unique engineering ability that plays a major role in the production of very special aircraft parts.

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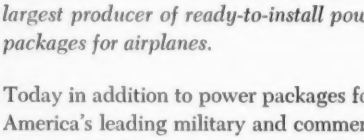
Today in addition to power packages for many of America's leading military and commercial planes, Rohr has been chosen to build complete, ready-to-install power packages for great, new jet-powered airliners such as the Convair 880, the Lockheed Electra Propjet, and the Boeing 707 (shown below).



World's largest producer of ready-to-install power packages for airplanes.

Main Plant and Headquarters: Chula Vista, Calif.
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Career opportunities for engineers and technicians.

IAS News

A Record of People and Events of Interest to Institute Members

Missile Scientist to Deliver Wright Lecture

H. Julian Allen (F), NACA Medal Winner Will Speak in Washington, D.C., on December 17

AN AERONAUTICAL RESEARCH SCIENTIST who early this year received NACA's highest honor, the Distinguished Service Medal, will deliver the IAS Wright Brothers Lecture, at 3 p.m., December 17, at the Natural History Building, Smithsonian Institution, Washington, D.C.

H. Julian Allen (F), Chief, High Speed Research Division, Ames Aeronautical Laboratory, NACA, will discuss "Hypersonic Flight and the Re-Entry Problem."

Mr. Allen, winner of the Institute's 1955 Sylvanus Albert Reed award, has contributed extensive research to the understanding of aerodynamics at speeds above Mach 5.

Missile, Wind-Tunnel Expert

Mr. Allen's work has made him an authority on long-range missile aerodynamics and on the design of transonic, supersonic, and hypersonic wind tunnels and test facilities. His most recent achievement has been the solution of missile heating problems and the discovery of blunting a missile's nose as a design feature to keep temperatures within acceptable limits.

His accomplishments also include development of a theory for predicting forces occurring at supersonic speeds on bodies at angles of attack, which is useful in high-speed missile and aircraft design. He has conceived and effectively supplied a variety of new research techniques and types of equipment for study of supersonic and hypersonic flight. Specifically, he developed two types of supersonic nozzles which made a wind tunnel a more flexible and effective tool; the technique of firing a gun-launched model upstream through a supersonic wind tunnel; and two methods for visual airflow at supersonic speeds.

H. Julian Allen

Blunt Nose Concept

Mr. Allen received the NACA medal 5 years after his basic research on blunting. The fundamental thoughts behind keeping the missile warhead sufficiently cool are contained in an NACA Research Memorandum published in 1953, "A Study of the Motion and Aerodynamic Heating of Missiles Entering the Earth's Atmosphere at High Supersonic Speeds," by Mr. Allen and A. J. Eggers, Jr.

This states, "A curious finding is that the maximum deceleration is independent of physical characteristics of a missile (e.g., mass, size, and drag coefficient) and is determined only by entry speed and flight-path angle, provided this deceleration occurs before impact....

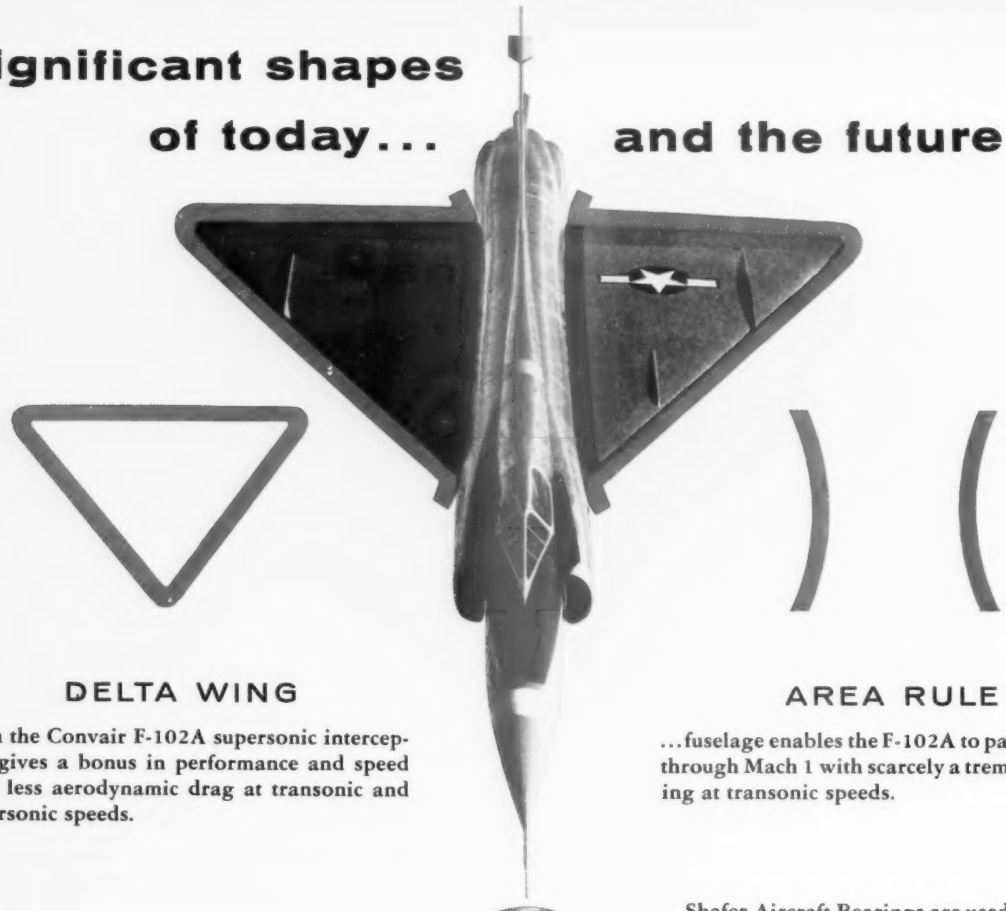
"If a missile is so light (ICBM-type missiles are considered sufficiently light) as to be decelerated to relatively low speeds, even if acted upon by low drag forces, then convective heating is minimized by employing shapes with a high pressure drag, thereby maximizing the amount of heat delivered to the atmosphere and minimizing the amount delivered to the body in the deceleration process. Blunt shapes appear superior to slender shapes from the standpoint of having lower maximum convective heat-transfer rates in the region of the nose. The maximum average heat-transfer rate per unit area can be reduced by employing either slender or blunt shapes rather than shapes of intermediate slenderness. Generally, the blunt shape with high pressure drag would appear to offer considerable promise of minimizing the heat transfer to missiles of the sizes, weights, and speeds presently of interest."

Joined NACA in 1936

Born in Maywood, Ill., in 1910, Mr. Allen was graduated from Stanford University with a B.A. in Engineering in 1932. He received the degree of Engineer from Stanford in 1935 and was awarded the William Roberts Eckart prize when his thesis was judged the best submitted for the degree.

Mr. Allen joined the staff of NACA's Langley Aeronautical Laboratory as a junior aeronautical engineer in 1936 after a brief period with Shell Chemical Company. He was transferred to Ames Aeronautical Laboratory, NACA, in 1940 and from 1941 to 1945 was Chief, Theoretical Branch. His current position as Chief, High Speed Research Division, of Ames, dates from 1945.

Significant shapes of today... and the future



DELTA WING

...on the Convair F-102A supersonic interceptor, gives a bonus in performance and speed with less aerodynamic drag at transonic and supersonic speeds.

AREA RULE

...fuselage enables the F-102A to pass smoothly through Mach 1 with scarcely a tremor of buffeting at transonic speeds.

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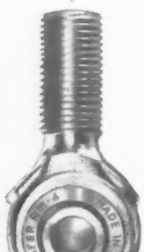
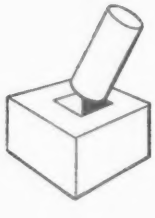


...Shafer Aircraft Bearings are used on F-102A control linkages because, size for size, a Shafer will deliver more capacity than any other self-aligning, anti-friction bearing.

DIME*

...is still the most important "shape" today and in the future. Shafer Bearings save plenty of Dimes in design and production stages and in service. Elimination of roller end wear and race surface scuffing alone adds to life. And Shafer original relubrication-in-service without disassembly adds 3 to 10 times to the service life of a Shafer Bearing over those not relubricated.

*The dime and the Shafer Bearing are shown actual size. The bearing is the new RM-4, conservatively rated at 1750 pounds in male and female rod ends.



ROUND PEGS IN SQUARE HOLES?

If that's the shape you're in with design parameters that seem to call for more bearing capacity than you can put in the allotted space, why not contact your Shafer Aircraft Bearing Specialist today, or write for Catalog 54 and get the full story. Shafer Bearing Division, CHAIN Belt Company, Downers Grove, Ill.

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Helicopter Development Award To Be Given at Annual Meeting

A new award of national recognition for outstanding work in the field of helicopter development has been created from the will of the late Lawrence D. Bell and will be conferred at the IAS Honors Night Dinner in January.

Known as the Grover E. Bell Award in honor of Mr. Bell's brother who died in an aircraft accident in 1913, it will be given annually "to the person or persons making an outstanding contribution to helicopter development during the preceding calendar year in the United States." This has been provided through a bequest by Mr. Bell to The Buffalo Foundation, Inc. The award was established to foster and encourage research and experimentation.

The founder of Bell Aircraft Corporation specified that the recipient should be chosen by a committee of three holding these offices: IAS President; American Helicopter Society President; and Chairman, Helicopter Council, Aircraft Industries Association.

The first award, including a medal, certificate, and cash honorarium, will be presented by Bell President Leston Faneuf.

Flight-Test Fellowship Worth Almost $5,000

Financial assistance to the amount of nearly $5,000 is assured the successful candidate or candidates in the Institute's competition for its 1958 Flight-Test Engineering Fellowship, opened last month.

The Fellowship award has a total value of $4,700. Winning candidates pursue 2 years of graduate study at Princeton University. Second-year renewal is contingent upon satisfactory performance during the first year.

Candidates must be United States citizens and possess a Bachelor's degree in engineering before June, 1958.

Application forms may be obtained by a request in writing, endorsed by a sponsor, addressed to Flight Test, Institute of the Aeronautical Sciences, 2 East 64th Street New York 21, N.Y.

The closing date for applications is March 1, 1958.

Two Institute Members Form Own Companies

Two members of the Institute, Thomas Wolfe (AF) and Adam Zahorski (AF), have formed their own companies in California—Thomas Wolfe & Associates and Zahorski Engineering, Inc.

Mr. Wolfe's firm, composed of professional and industrial specialists in finance, management, marketing, and Government relations, has been organized specifically to serve the aviation industry. Mr. Wolfe recently resigned his position as Director of Requirements, Procurement and Distribution, Department of Defense, to direct his firm from its offices at 530 West Sixth Street, Los Angeles.

Mr. Zahorski's firm, located at 133 East Canon Perdido Street, Santa Barbara, plans research and development in the fields of structures, electronics, and mechanics, with emphasis on industry requirements and problems associated with elevated temperatures in aircraft and missiles.

The firm reports that it is working on a new type of fuselage structure of light weight and high thermal characteristics, studies of high thermal aircraft and missile wings, use of plastics for insulated liquid oxygen tank containers, materials subjected to rocket exhaust heat, hydraulic analog instruments, high thermal pressure pickups, environmental testing equipment, and studies of high intensity blasts on structural configurations.

Mr. Zahorski formerly was Chief of Structures, Aerophysics Development Corporation.

Arthur E. Raymond to Receive Daniel Guggenheim Medal

Arthur E. Raymond (HF), 1946 President and a Founder Member of the Institute, will be awarded the Daniel Guggenheim Medal at the IAS Honors Night Dinner in January.

Mr. Raymond, Vice-President—Engineering, Douglas Aircraft Company, Inc., was selected by a 23-member international Board of Award for "the development of a long line of successful civil and military aircraft and for notable contributions to aeronautics in public service."

Mr. Raymond has worked on nearly all Douglas aircraft since 1925 when he joined the firm. He delivered the second Dr. Albert Plesman Memorial Lecture (honoring the late founder of KLM Royal Dutch Airlines) at Delft, Holland, in September. He is a member of the National Advisory Committee for Aeronautics and the National Academy of Sciences.

The medal is given annually by The Daniel Guggenheim Medal Fund, Inc., to honor persons who make notable achievements in the advancement of aeronautics. Provision for the medal was made in 1928 by the gift of a fund from The Daniel Guggenheim Fund for the Promotion of Aeronautics. Presentation is sponsored by one of three societies: the IAS, ASME, or SAE.

Necrology

Major Merwin Kanter

News of the death of Major Merwin Kanter (A) last June has reached the Institute. He was 41.

Major Kanter, a native of St. Paul, Minn., entered the Air Force in 1941. At the time of his death he was a Research and Development Adviser to the Japanese Defense Agency.

He was graduated from the University of Minnesota in 1940 with Bachelor degrees in chemical and industrial engineering, and he received a Master's in aeronautical engineering in 1951 from the University of Michigan where he majored in guided-missile studies and was first in his class.

Major Kanter was in charge of guided-missile programing at Patrick AFB prior to his Japanese assignment. He held positions during the war as Supervisor of Maintenance at six Air Force flying schools and was a test pilot, a research and project engineer in the Propeller Laboratory at Wright-Patterson AFB, and later a Project Officer, Surface-to-Surface Guided Missiles, Holloman AFB.

Captain John E. Ostrander, Jr.

The Institute has received news of the death of Capt. John E. Ostrander, Jr., USN (Ret.) (AF), on June 28. He was 63.

Captain Ostrander, who led the first

Can you use the talent that built 1,500 Y-4 bombsights on schedule?

These General Mills technicians are representative of the production talent that built more than 1,500 Y-4 bombsights, 1,500 coordinate converters, 1,400 azimuth and sighting angle indicators and 1,400 amplifier and power supply units—and, delivered them to the Air Force *on time*. Here the men inspect a bombsight before it progresses to the next stage of production.

Because we have the highly skilled men—and the men have the specialized tools and machines—we produce precision piece parts or complete, complex assemblies to meet the most exacting requirements.

While building the Y-4 bombsight, we improved original design, exceeded USAF specifications. In addition, our thorough testing facilities assured delivery of only perfect instruments.

Such performance has come to be expected of us and has benefited many other customers. We'd like to help with your production problems too.

Booklet Tells More, explains mechanical and electro-mechanical production facilities. Send to Dept. AR-5, Mechanical Division, General Mills, 1620 Central Ave. N. E., Minneapolis, Minn.

No slow-downs for the B-47—Bombsights ready in advance! During production of the B-47 Stratojet, not a one was kept from the ready-line for lack of a bombsight. The same developmental, engineering and production skills that gave the Air Force on-time delivery are available to speed production of your products.

MECHANICAL DIVISION

CREATIVE RESEARCH AND DEVELOPMENT + PRECISION ENGINEERING AND PRODUCTION

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aircraft squadron to land on the U.S.S. "Saratoga," was graduated with distinction from the Naval Academy in 1917. He attended the Academy's Postgraduate School and later received his Master's degree in mechanical engineering from Massachusetts Institute of Technology where he specialized in aviation ordnance.

Posts held by Captain Ostrander include Executive Officer and Commander of Fighting Squadrons Six and Three; Head, Armament Section, BuAer Design Division; Navigator and Air Officer, U.S.S. "Wright"; Aviation Member, Navy Department War Plans Division; Naval Examining Board (Member); and Production Superintendent, Naval Aircraft Factory.

Captain Ostrander was born in Moscow, Idaho, on September 29, 1894.

Fidia J. Piattelli

The Institute has received news of the death of Fidia J. Piattelli (AF) on August 25. He was 50.

Dr. Piattelli was Chairman, Israel Society of Aeronautical Sciences, an adviser to the Israeli Ministry of Defense, and Chief Aeronautical Engineer, Bedek Aircraft, Ltd.

He was born in Rome in 1907 and studied at the University of Rome where he received doctorates in industrial engineering and aeronautical engineering. He won the 1933 Rome competition for sailplane design.

Dr. Piattelli joined Fiat at Marina di Pisa as assistant designer in 1935. From 1936 until his departure for Israel in 1945, he was Assistant Chief Designer of the Reggio Emilia branch of the Caproni firm.

In Israel he was General Manager of Maof, Ltd. (Palestine Aircraft Company) until 1948 when he became Head, Engineering Department, Israel Air Force.

Edward W. Rice, Jr.

Word of the death of Edward W. Rice, Jr. (A), on June 9 has reached the Institute. He was 34.

Mr. Rice was an engineer for United Air Lines, Inc. He also served for 3 years as an Air Force pilot, flight engineer, and instructor. He held a single- and multiengine commercial pilot's license.

Mr. Rice was a native of Santa Cruz, Calif., and a mechanical engineering graduate of Stanford University. He also attended Texas Technological College.

Bryan R. Noton (M), Senior Scientific Officer, The Aeronautical Research Institute of Sweden (FFA), during the past 2 years has been giving invitation lectures at international conferences in Sweden, Holland, Germany, England, and the U.S.A. The 29-year-old scientist has prepared nearly 50 reports, papers, and articles on several aeronautical subjects. Much of his research has covered honeycomb sandwich construction. The FFA soon will publish his work on "Various Tests on Aluminum Honeycomb Cores Bonded with Redux 775 and a Comparison in the Form of Design Curves with All Known Aluminum Honeycomb Cores."

NEWS OF MEMBERS

▶ **Charles S. Draper** (F), Head, Aeronautical Engineering Department, Massachusetts Institute of Technology, and Director, Instrumentation Laboratory, has been awarded the ASME Holley Medal. Given for a "great and unique act of engineering genius," Dr. Draper received the award for discovery of a revolutionary new principle for controlling guns fired from moving platforms at moving targets.

Members on the move . . . .

This section provides information concerning the latest affiliations of IAS members. All members are urged to notify the News Editor of changes as soon as they occur.

Serge A. Alexeeff (M), formerly a Weight Engineer, Vertol Aircraft Corporation, last May joined the National Aeronautic Association as Senior Engineer, Structures.

Capt. Paul J. Burr, USN (AF), formerly Executive Director, BuAer Field Activities, has been named Director of Maintenance Division.

Gerald E. Dodson (A), formerly Project Engineer, Angelus Aircraft, Inc., has joined the American Aerophysics Corporation as a consultant in the organization and operation of the firm's new fiberglass-reinforced plastic laminate division.

Michael E. Gluhareff (F) has been appointed Engineering Manager, Sikorsky Aircraft Division, United Aircraft Corporation, to succeed recently retired Igor I. Sikorsky (HF). Mr. Gluhareff has been in charge of all Sikorsky helicopter design, research, and development.

Richard B. Hubbard (M), formerly President, ERCO Division of ACF Industries, has been elected to the new post of Vice-President and Assistant to the President, Pacific Airmotive Corporation. Mr. Hubbard also is a member of the REVIEW Editorial Advisory Committee.

Gaylord W. Newton (M), Manager, Applications Engineering, General Electric Company's Aircraft Nuclear Propulsion Department, has been appointed a civilian consultant to the technical advisory panel on aeronautics for the Assistant Secretary of Defense.

Terrence R. F. Nonweiler (AF), formerly Senior Lecturer, Aerodynamics, Cranfield College of Aeronautics, Great Britain, has been appointed Senior Lecturer in the newly formed Department of Aeronautical Engineering, Queen's University, Belfast, Northern Ireland.

Dexter Rosen (AF), recently in charge of Bell Aircraft Corporation's Cleveland Laboratory, has been appointed Administration Department Manager for the firm's Guided Missiles Division.

Robert F. Stoessel (M) has been advanced to the newly created position of Hercules Commercial Sales Manager, Lockheed Aircraft Corporation, Georgia Division. He was formerly Manager, Sales Engineering.

Norman L. Winter (M) has been named Manager, Countermeasures, a newly organized group for military electronic "jamming" equipment within the Sperry Gyroscope Company, Division of Sperry Rand Corporation.

Pearl I. Young (M), who taught engineering physics at Pennsylvania State University for the past 10 years, has returned to the National Advisory Committee for Aeronautics as a Technical Literature Analyst at Lewis Flight Propulsion Laboratory.

Attention Members!

All Members of the Institute are invited to submit material concerning their activities for publication in the news columns of the *Aeronautical Engineering Review.*

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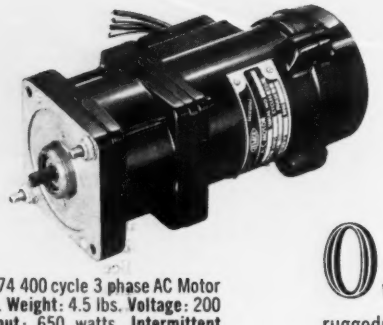
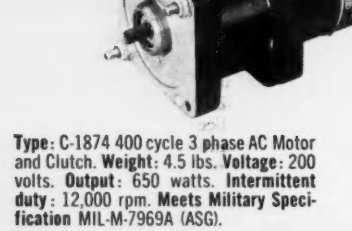
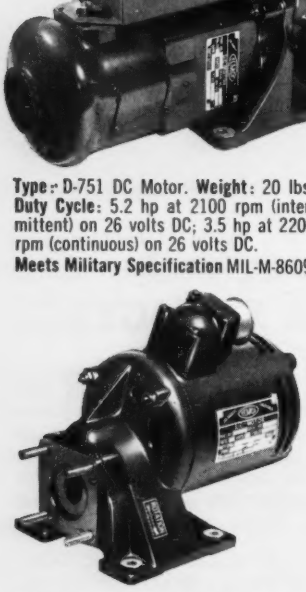


Type: C-1874 400 cycle 3 phase AC Motor and Clutch. **Weight:** 4.5 lbs. **Voltage:** 200 volts. **Output:** 650 watts. **Intermittent duty:** 12,000 rpm. **Meets Military Specification** MIL-M-7969A (ASG).



Type: D-751 DC Motor. **Weight:** 20 lbs. **Duty Cycle:** 5.2 hp at 2100 rpm (intermittent) on 26 volts DC; 3.5 hp at 2200 rpm (continuous) on 26 volts DC. **Meets Military Specification** MIL-M-8609.

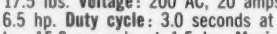


Type: D-899 400 cycle 3 phase AC Motor. **Weight:** 11.25 lbs. **Volts:** 200 volts. **Load:** 2.75 hp continuous output. **RPM:** 3140 rpm output at gear box. **Power factor:** 83%. **Overall efficiency:** 76% for entire unit. **Meets Military Specification** MIL-M-7969A (ASG).

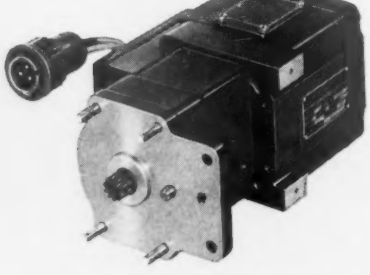
Over the years the precision, ruggedness and reliability of EEMCO products has been proven time and time again. The consistent, exceptional performance of these low-weight, high-output motors, a few of which are illustrated, has earned EEMCO industry-wide recognition. In this highly specialized field, where perfection is imperative, the widespread use of EEMCO motors and of EEMCO's equally reliable actuators is eloquent testimony.

Type: D-932 DC Motor. **Weight:** With radio noise filter—13 lbs., without same—12.4 lbs. **Terminal voltage:** 27.5 DC plus or minus 1.5 volts. **Load:** From .5 hp minimum to 2.6 hp maximum. **Speed:** Continuous at 12,000 rpm, plus or minus .005%. **Speed Control:** By frequency regulator supplying control field. **Meets Military Specification** MIL-M-8609 (ASG).

Type: D-638 400 cycle AC Motor. **Weight:** 17.5 lbs. **Voltage:** 200 AC, 20 amps at 6.5 hp. **Duty cycle:** 3.0 seconds at 6.5 hp, 15.0 seconds at 1.5 hp. **Maximum capacity:** 6.5 hp. **Continuous rating:** 5 hp at 2300 rpm, 15.8 amps, 200 volts. **Meets Military Spec.** MIL-M-7969A (ASG).



Type: D-800 400 cycle 3 phase AC Motor. **Weight:** 8.75 lbs. **Voltage:** 208 volts. **Horsepower:** 2.5 hp. **Continuous Duty:** 11,300 rpm; Equipped with thermal protector. **Meets Military Specification** MIL-M-7969A (ASG).



Type: D-927 DC Motor. **Weight:** 7.25 lbs. with 2-circuit noise filter for ungrounded systems. **Weight of filter:** 1 lb. **Terminal voltage:** 27 volts, 18 amps. **Load:** 0.5 hp. **Speed:** Continuous at 9900 rpm. **Meets Military Specification** MIL-8609.

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CORPORATE MEMBER NEWS

• **Aerojet-General Corporation's** man-made "igloo" for launching research rockets in the cold area of Fort Churchill, Canada, has metal panels forming lower walls which open for escaping thrust and exhaust gases when a rocket is fired. A turntable-type pad permits the guide tower to revolve and slope up to angles of 10 deg. in any direction. This is said to minimize the effect of heavy winds on the slow-rising Aerobee-Hi (see photo, this page). Aerojet also has announced it is manufacturing warheads for the Nike Hercules that are made of glass fabric annealed with resin. The firm's subsidiary, Aerojet-General Nucleonics, has installed an AGN-210 portable reactor at Argonne National Laboratory Training Institute, University of Chicago. Gordon Banerian, Manager, Turbo-Machinery Division, has been appointed to the company's WS-107A (Titan-ICBM power plant) Technical Advisory Committee.

• **Aeroquip Corporation** has announced a royalty-paying licensing agreement granting The Weatherhead Company rights to produce and sell Aeroquip's "super gem" fittings for Teflon hose assemblies in the United States and Canada. The firm also announced the following appointments: Fred W. Schwier, Assistant to the Aircraft Sales Manager, Jackson Division; William H. Rowley, Manager, Military Requirements; and A. H. Cassidy, Industrial Sales Manager, Marman Division.

• **Aluminum Company of America** reports it is packaging in dry ice sheets of wing skin for the Douglas DC-8 to keep it from age-hardening before cutting and fabrication at Douglas facilities. Alcoa also announced it is entering the business of producing foamed-plastic insulated panels for fabrication into other products. The firm reports that a revolutionary process for laminating aluminum, wood, glass, porcelain, or other materials to a rigid core of foamed plastic offers particularly broad possibilities in the architectural field. Alcoa's Chairman of the Board and Director, Arthur Vining Davis, has resigned.

• **American Airlines, Inc.,** has begun DC-7 aircoach service between Chicago, Ill., Los Angeles, Calif., and between Chicago and San Francisco, Calif. The air line also announced the appointments of Henry O'Neil to Director of Advertising and Meck Howlett to Director, Sales Promotion, in a move to reorganize its Merchandising Department.

• **Amphenol Electronics Corporation** is marketing new environmentally sealed rack and panel connectors designed for potting. They are available with 57 electrical contacts and two coaxial connectors or 75 electrical contacts with three coaxial connectors, according to the firm. The units are said to be electrically rated at 7.5 amp. per contact at 600 vdc.

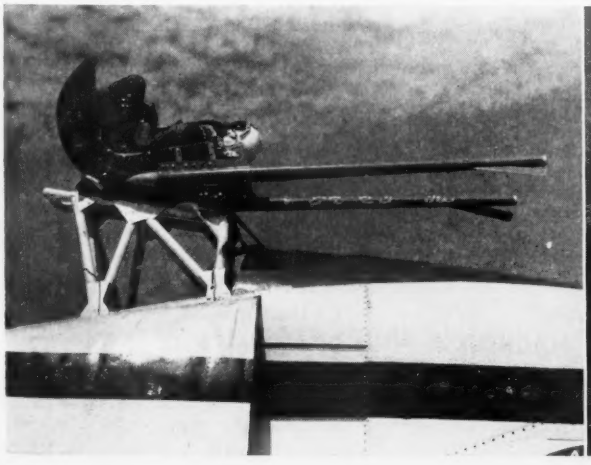
• **Avien, Inc.,** has announced the appointment of Murray Heyert as Manager, Missile Products Sales.

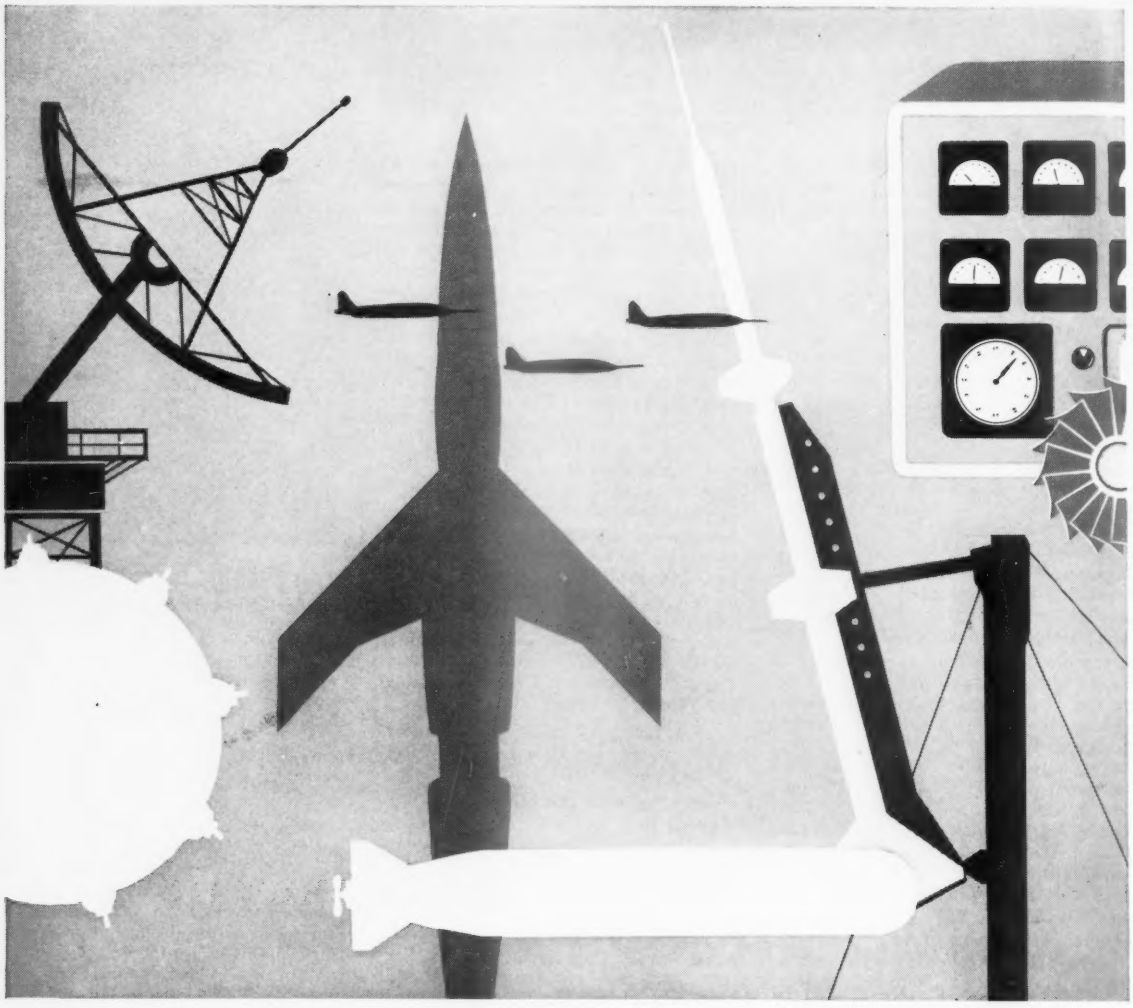
• **Beech Aircraft Corporation** has announced that one of its dealers recently flew a four-place Beechcraft Bonanza nonstop from Fresno, Calif., to Kingman, Kan. (1,226 miles), in 8 hours and 17 min. Specified range for the aircraft is 1,170 miles, the firm said.

• **Bell Aircraft Corporation** and the Navy have announced automatic jet aircraft landings on the carrier U.S.S. "Antietam," accomplished with a new combination radar and radio system that takes over from the pilot while the airplane still is some distance from touchdown. Radar locates the aircraft and determines its altitude and location with relation to the carrier deck, according to the firm. Then a computer takes over, sending necessary course corrections to an automatic pilot which directs the airplane into the desired flight path. When the Bell system "locks on" to the airplane, the pilot relinquishes control. The firm also announced that the USAF is activating its first Rascal guided-missile squadron: the rocket-powered missile will be carried by SAC B-47's. (*Continued on page 78*)

A specially constructed "igloo" all-weather launching facility was designed by architect-engineers of the Aerojet-General Corp. for launching Aerobee-Hi and other rockets at Fort Churchill, Manitoba, Canada, during the International Geophysical Year. Army Engineers built the "igloo" to permit launchings in the low-temperature area. The 5-story building is 40 ft. square, has a steel frame, and is metal-covered. As shown, it projects the tower that guides the rocket.

A development of the Industry Crew Escape Systems Committee, the "B" (or aerial bobsled) seat was successfully ejected from a supersonic rocket sled (Convair F-102A cockpit) for the ARDC by scientists of Coleman Engineering Company, Inc. The twin booms, corresponding to the long stick of the ancient Chinese skyrocket, perform a stabilizing function. The booms are released from a telescoped position by a charge during ejection.





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PROFESSIONAL NOTES AND REPORTS

Engineering and Scientific Briefs from Correspondents Around the Globe

Hydrogen in Aluminum Subject of U.S.S.R. Research

◆ A recent (1955) paper by M. M. Karnaukhov and A Kh Urazgil'deyev, titled "Hydrogen in the Metal During Acid-Open-Hearth Melting," has been found to contribute valuable fundamental information toward understanding of the behavior of hydrogen in aluminum alloys and might well be extended to other metals. Although at present it seems to offer no practical leads as to how to improve elimination of hydrogen from molten metal, it is possible that better understanding of the forms in which hydrogen is present may eventually lead to development of better dehydrogenation agents.

The authors made tests to determine the effect of direct current on the hydrogen in solution in aluminum and its alloys. The results were evaluated on the basis of gas content and porosity of solidified metal.

(1) A direct-current treatment for 20 to 30 sec. degasified a series of silumin (DA3) heats. This would indicate that the hydrogen was present in ionic form.

(2) The same treatment had much less effect on pure aluminum and UA3 alloy, although there was nonuniform hydrogen distribution after the treatment.

(3) The addition of small amounts of sodium or lithium prior to the direct-current treatment promoted the speed and completeness of degasification. The cause is believed to be attributable to the formation of hydrides, with the hydrogen present in ionic form. Thermodynamic calculations confirmed the possibility of forming sodium and lithium hydrides.

(4) The test data are interpreted as indicating that hydrogen can be present not only as ions (either positive or negative) but also in colloidal particles or complex ions—and as atoms and even as molecules.

(5) Consequently, account must be taken of all these possibilities in considering the behavior of hydrogen in molten metals since its behavior will depend on the form in which it is present.

New Radio Aid Discussed in French Institute Paper

◆ In a paper on "The Radio-Web System—Functioning and Possibilities," the Institut du Transport Aerien outlines the principle upon which this new radio aid, developed by Pierre Gaudillere, is based. Also indicated are the various services it can render navigators and air traffic controllers. ITA is a nonprofit-making international association with headquarters in Paris.

Like all other hyperbolic systems, the Radio-Web is based on the measurement of the time elapsing between reception of two simultaneous transmissions from stations in a slave-to-master relation. This type of measurement affords great accuracy in aircraft localization. The Radio-Web offers the possibility of combining several hyperbolic channels into a square pattern grid or a grid of meridians and parallels—or even of curves adapted, for instance, to the shore line of an estuary. This versatility makes the system applicable to long-range and short-range navigation, as well as to the approach and landing phases of flight.

The system also can replace radar by displaying before the eyes of the traffic controller a P.P.I. showing all aircraft in the control area equipped with a Radio-Web receiver and transmitter. The system has the advantage of being insensitive to fog and atmospheric precipitations. Moreover, it will have a much wider range than present radar types, and, since it uses surface waves, it also will indicate the position of aircraft flying below the horizon of the site where the ground receiver of the P.P.I. is located.

For using the Radio-Web as an anti-collision device, two potential techniques are available. The first is the installation of an air-borne Radio-Web receiver with a cathode-ray oscillograph similar to that in the traffic control center. The second is the relaying to the aircraft of the position plan worked out at the control center. (It would, of course, be necessary to provide the pilot with proper means of identifying his aircraft on the position plan, but this could be achieved easily by a selecting device.)

There also is the possibility of using the position signals picked up by the aircraft to develop a flight log similar to that developed by Decca.

Not only does the Radio-Web constantly indicate the position of the aircraft to the pilot and the traffic control services—which implies speed and flight path indications—but it also can provide automatic and selective air/ground radio communication.

The flexibility of the interference fringes phenomenon is such that numerous variations of the system can be contemplated. According to the inventor, equipment on the ground would cost less than that required by other systems, and the cost, weight, and space taken by the air-borne equipment also would be extremely low.

Solid Propellant Rockets to Be Used in Japanese Tests

◆ A Japanese delegate to the URSI (International Scientific Radio Union) Conference held August 26 to September 5, in Colorado, described the Japanese plan to try a number of rockets using solid propellants. There are two parallel developments—a series of rockets fired from the ground and another of rockoon type (fired from balloons). The Japanese scientist, a Professor Maeda, outlined the projects to be undertaken and gave a description of the rocket to be used in each case. The projects that are planned are as follows:

(1) Solar Radiation. This has long been one of the problems in solar phenomena. The determination of the solar constant on balloon and rocket flights has led to widely varying results. In these measurements, a soft X-ray Geiger counter with telemetry will be installed in a rocket K-5 RS, which will be fired from the ground. A sigma-type rockoon will be used.

(2) Cosmic Rays. Information on the high-altitude cosmic-ray intensity is very meager. In this measurement, type K-4 C will be used for ground firing. A sigma-type rockoon will also be used.

(3) Density of Ions. This experiment is of great importance in connecting

(*Continued on page 74*)

A group of American delegates inspected the Vickers-Armstrongs (Aircraft) Ltd. manufacturing facilities at Weybridge and at Hurn on September 5. The above picture was taken at the Hurn Plant.

Presidents of the two Societies, Mundy Peale (*left*) and Sir George Edwards (*right*), discuss technical features of the Vickers' Vanguard at the mock-up at Weybridge.

SIXTH ANGLO-AMERICAN CONFERENCE

The scheduled sixth meeting between the IAS and the RAeS of Great Britain took place September 1–15 in and about London and at Folkestone. About 100 Americans, accompanied in some cases by wives (and a few children), took part. The program included the Annual SBAC Flying Display at Farnborough, the RAeS Garden Party at Wisley Aerodrome, and a number of group visits to a selection of British manufacturing, research, and educational institutions. The pictures accompanying the Editorial give a fair cross section of the range of activities and an indication of the number and caliber of the American delegates who participated.

In Retrospect

It would be gratifying to be able to report without qualification that the Sixth Anglo-American Conference was the best ever. In most respects it was—but to those who have been participating year after year, there were disappointments. It should not be inferred that the overall result was questionable. Far from it. It was apparent, however, that some of the elements of the program could have been improved. Some comment appears warranted as a guide for the future.

As for the traditional hospitality of our hosts, nothing but the best can be said. No effort was spared, either officially or unofficially, to make the American delegates feel most welcome and entirely "at home." The technical field trips that were laid on by the RAeS in conjunction with the several manufacturers were very well organized. Some of them involved complicated bus, rail, and air transportation. All of them went off without a hitch. The same may be said for the ladies' tours, which were equally complicated. The vagaries of the English weather and the complications of bedding-down large groups of itinerant Americans in up-country British hotels posed problems that were never beyond the capabilities of Dr. Ballantyne's staff. The RAeS people did an outstanding job in seeing that everything went off on schedule and that all participants were happy.

The purely social side of the program also went off very well. From the opening reception at 4 Hamilton Place on September 1 to the final tea and cocktails at Sir George Edwards' house following the Garden Party at Wisley, the Americans (and, in fact, all participants) had a wonderful time. The only complaints that we heard came from Americans who worried about adding too many pounds of personal weight as a result of the fantastic array of things to eat and drink that were continually spread before them. (Those of us who remember the thin fare of the 1947 and 1951 periods could see that the situation in England had improved considerably in the intervening years.) Some of our friends who tried to explain how to make American old-fashioneds or whiskey sours to the men-behind-the-bars soon gave up and presently became loud in their praises of "Gin-and-It" and other local concoctions. Whatever their tastes, however, no one could complain of shortages.

The Mayor's Reception and Cabaret and the Conference Dinner at Folkestone were notable events. The latter had a predominately Scottish flavor. The haggis proved to be a real conversation piece. The bagpipes and drums, on the other hand, going full out in the confines of the Metropole's Ballroom, would certainly be classed as "*anti*conversation" pieces!

(*Continued*)

On the receiving line at Folkestone (*left to right*) Miss Sandra Peale, Mrs. Mundy Peale, President Peale, Lady Edwards, Sir George Edwards. Back to camera—Dr. Ballantyne's daughter, Caroline.

Distinguished visitors at Folkestone, Dr. von Kármán and Dr. Wattendorf, are greeted by President and Mrs. Mundy Peale.

Lord Mayor of Folkestone and his Lady greet IAS Publications Director Welman Shrader in receiving line at Folkestone.

Tea for the American ladies at the home of Sir George Edwards. *Clockwise*, the group includes Lady Edwards (*standing, left*), Mrs. N. E. Rowe, Mrs. Elmer Sperry, Mrs. D. L. Hollis Williams, Mrs. Frederick Felberg, and Mrs. Paul Johnston.

Above, left, delegates group at Fairey Aviation Company, Ltd., White Waltham, on September 2. *Above, right,* inspection party at National Gas Turbine Establishment, Pyestock, September 2.

The party which visited Short Brothers & Harland Ltd., Belfast, September 5, and Armstrong Whitworth Aircraft Ltd., Coventry (shown above), September 6.

Elmer Sperry of the IAS group discusses a point with Chief of Design, D. Keith-Lucas, of Short Brothers, and Jim Simmons of the RAeS.

Past Presidents of the IAS, Dryden and Millikan, form part of an attentive group at a briefing at the Royal Aircraft Establishment (Bedford) on September 6.

IAS party examines manufacturing processes and a model of full-scale wing testing facilities at Short Brothers, Belfast.

Anglo-American Conference *(Continued)*

Probably the most important (and certainly among the most enjoyable) elements of the Conference were the more intimate technical conversations that were held during the week at Folkestone. The discussions that took place across the luncheon and dinner tables between the British aircraft manufacturers' groups and certain of the American delegates probably represented as valuable an interchange of views as those that took place in the formal technical sessions of the Conference.

It is in this latter department that some criticism is justifiable. It appeared to be the consensus that the technical papers presented were not, as a whole, up to the standards that the delegates had reason to expect. At the risk of an accusation of national bias, we think it can be said fairly that the American papers stood up better than the British. One or two of the latter proved to be astonishingly elementary in character. Some of the difficulty could possibly be laid to poor selection of topic. Certainly, in several cases, Security was obviously the chief culprit. It would have been preferable, for example, to have skipped any discussion of nuclear problems than to present what was obviously a "filler." Also, apart from language difficulties, the American presentations compared favorably with the British. This was an improvement over the situation at some of the earlier Conferences.

In spite of detailed instructions and of pre-Conference pleas for attention to this detail by both Societies, many of the slides thrown on the screen were absolutely terrible. Admittedly, light conditions and the projection equipment in the lecture rooms were not of the best, but how any practical-minded lecturer can expect an audience to read a mass of minuscule typewritten figures and formulas in white on black is beyond comprehension. Curiously enough, some of the worst examples came from companies that are supposed to have excellent "visual aids" departments. This seems to be one of the most difficult lessons for many lecturers to learn, and it should be the simplest.

As usual, the American group appeared far less willing to enter into discussion from the floor than the British. This has always been the case. It is a matter of tradition and training, and, of course, again the security problem raises its head. There were exceptions—notably the informal postlecture discussions of STOL-VTOL aircraft and of "sandwich" construction. We do not care particularly for the formalized, prepared type of discussion of which the British are fond, but we do think that Americans, by their reluctance to get on their feet and to say something, missed a number of opportunities to make a real contribution to the Conference.

In spite of these somewhat critical comments, it is certain that everyone who participated felt that the Sixth Anglo-American Conference was a success. Plans have been made by the joint Councils of the two Societies for the Seventh Conference, to be held in the United States in the first 2 weeks of October, 1959. The tentative program calls for assembly and technical sessions in New York City, to be followed by a tour of aircraft activities in the northeast section of the country. Approval has been given for an inspection of the Lewis Flight Propulsion Laboratory of the NACA in Cleveland (it will be remembered that during the two previous Conferences held in the U.S., visits were made at the Langley and Ames laboratories). To tie Canadian interest into the Conference, a visit under CAI auspices will be made across the border, and selective plant tours will be set up among the industrial groups along our own Eastern Seaboard. We are all looking forward to that meeting and to our opportunity to repay our British friends in a small degree for the magnificent hospitality extended to us during the Sixth Anglo-American Conference in 1957. S.P.J.

Officers of Short Brothers discuss design features and expansion plans with *(left)* Bob Dexter and Joe Maitan of the IAS and *(right)* Boeing's representative B. K. Bucey and IAS Past President C. J. McCarthy.

Vickers' David Sykes points out a few Viscount design details to an IAS group, including President Peale and John Ide.

Design of large output rocket motors with predictable performance remains an art, though an effort is being made to bring reliability into the realm of science. Data in this revealing report, written especially for the Review, include a new approach that promises useful results in stability as well as combustion problems.

Notes on Problems in Combustion Instability of

CONSIDERABLE experience has been accumulated by the industry in designing rocket chambers and rocket systems of certain magnitude (level of thrust output). However, difficulties are encountered in designing large output units. These difficulties arise from appearance of oscillatory combustion with large pressure amplitudes (also called combustion instability). Some of the oscillatory combustion phenomena are damped, but many are undamped and lead to destruction of the combustion chamber either by high-amplitude, low-frequency pressure variation (chugging) or by local burnout of the combustion chamber walls and injector plates. This burnout is due to extreme heat-transfer rates caused by high-frequency and high-amplitude pressure and gas-velocity fluctuations (high-frequency oscillatory combustion, also called "high-frequency instability" or "screaming").

It seems to be accepted that chugging is a low-frequency oscillatory combustion phenomenon coupled with feedline and structural modes of oscillations. The high-frequency oscillatory combustion is considered free from feedline and structural coupling. Chugging is amenable to system-type analyses. However, nonlinear effects have to be considered for the investigation of high-frequency oscillatory combustion.

In spite of the intensive experimental and analytical work done in this country and abroad, many of the physico-chemical phenomena of the rocket chamber are still not completely understood. Some of these can be approached analytically, others are amenable only to experimental investigations. This latter group of phenomena will be discussed first.

Rather than a survey of the state of the art, this paper conveys some of the thinking of the author and describes briefly work by the Mechanical Engineering Department of the Polytechnic Institute of Brooklyn. Part of this work is supported by the Office of Scientific Research and the Aerodynamics Research Laboratory (WADC) of the USAF.

The author is Professor of Mechanical Engineering.

PHYSICO-CHEMICAL PHENOMENA

There are a great number of parameters involved in any rocket motor. However, if the physico-chemical phenomena are broken up into basic groups, each of these can be investigated by strictly controlled experiments. The two least-understood basic groups of phenomena in the rocket chamber are: injection, and evaporation and combustion. These phenomena may be studied as they are affected by chamber pressure, chamber geometry, and fuel-oxidizer ratio (for any chosen fuel-oxidizer combination).

No reliable information is available for the evaluation of the relative importance of the liquid-phase and vapor-phase combustion. However, it is thought that the vapor-phase combustion is by far the more important of the two. The preparation of oxidizer and fuel for combustion by preheating is achieved by means of convection (recirculation of hot gases), radiation, and conduction (probably the least important mechanism). However, the mechanism of recirculation of the hot gases is little understood. This is one of the phenomena which is being investigated under carefully controlled conditions at the Polytechnic Institute of Brooklyn. Since the combustion in rocket chambers is a non-steady phenomenon, the investigations are being carried out under steady and periodically changing chamber pressures.

A systematic investigation of efficient combustion as affected by location and orientation of injector jets is also very important. Aerothermodynamic recirculation of combusting gases might be influenced and governed by judicious distribution and location of injectors. Combinations of downstream injection (accepted practice) with side-injection and reverse injection will also be investigated.

Apart from the experimental work being carried out, a new analytical method is being developed for the study of high-frequency oscillatory combustion. Before outlining the new approach, a brief discussion will be given of available methods for investigation of

ROCKET MOTORS

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oscillatory combustion in rocket motors and other combustion chambers.

Analytical Methods

The low-frequency instability of rocket motors seems to be well understood, and the developed analytical methods are useful in predicting their behavior in this instability range. However, analyses used for high-frequency instability are still in need of improvement. C. C. Ross and P. P. Datner presented an excellent review of the state of the art in 1953,[1] and C. C. Ross pointed out basic considerations regarding scaling of rocket motors in 1955.[2]

Two distinct approaches are available in the literature for the investigation of the complex phenomena in rocket motors. One employs the time lag concept, and the other employs the general equations of aerothermochemistry. Both of these methods have certain advantages, but they also have distinct disadvantages. It is of interest to note that both of these methods were proposed by Dr. Theodore von Kármán.

The time lag is essentially an integral concept and does not take detailed account of the aerothermodynamic and chemical kinetic phenomena. It is not necessary to make the usual simplifications—linearization, etc.—in analyses using the time-lag concept, but the complexity of the resulting equations makes it imperative to do so.

The time lag may be interpreted as the integral of detailed transport and chemical kinetic phenomena. To date, there are at least two important deviations from the originally proposed constant time lag (as introduced by Dr. von Kármán and used in analyses by Summerfield and Tsien[3, 4]), those introduced by L. Carocco[5] and by Barrère and Bernard.[6] All analyses employing the various time lag concepts use linearized equations which allow the determination of certain limiting conditions—limits of stability, etc.—but not the complete analysis of the essentially nonlinear phenomena in combustion chambers and rocket motors.

The final answer for predicting the behavior of rocket motors and other combustion chambers will come from analyses which use the complete equations of aerothermochemistry. For the time being, many simplifying assumptions have to be made when employing this approach. This is partly due to inadequate knowledge of the chemical kinetic processes involved, and partly due to the complexity of the resulting equations which take all the detailed phenomena into account. The fundamental equations in aerothermochemistry are presented in a paper by Dr. von Kármán.[7] (For our purposes, the similitude analyses are understood to be included in those types of analyses. Reference should be made to Weller's paper dealing with the similitude type of approach[8] and some recent work of S. S. Penner.)

A new approach developed by the writer promises useful results in stability as well as in scaling problems, not only in rocket motors but in other jet propulsion devices as well. The important features of this analysis are that the nonlinear character of the equations is maintained and that local chemical changes, mixing, and other phenomena can be taken into account by considering the local variation of the characteristic gas properties in the chamber. The new method and some of the results obtained will be reported in a technical paper in the near future.

The analysis is valid for subsonic as well as for supersonic regions. It seems important that the geometric configuration of the combustion chamber be taken into account in stability analyses. As a matter of fact, preliminary investigations have shown that even for steady operation the geometric configuration is important for the fulfillment of certain "optimum" requirements in rocket motors. This dependence of the geometric configuration of combustion chambers on the aerothermochemical phenomena can be assessed by a simple steady-state analysis. This will be discussed next. (For details not presented here, reference should be made to reference 9.)

Steady Aerothermochemical Analysis of Rocket Motors

Although attempts have been made to connect chemical kinetics with aerothermodynamic processes in rocket combustion chambers, no comprehensive investigation can be found in the literature. An analysis was undertaken to fill this need.

The analysis is carried out in two parts. First, chemical kinetic calculations are made for desired energy release distributions. Then, the flow parameter and the geometric configuration are determined from aerothermodynamic considerations. Since the equations used are well known, only an outline is given here. Certain simplifying assumptions are used which do not restrict the general validity of the analysis. The analysis is valid for combustion chambers of other jet

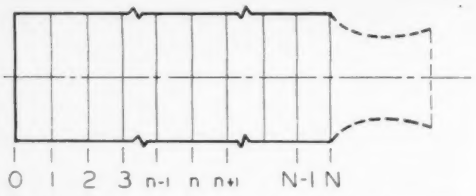

FIG. 1. Schematic diagram of combustion chamber.

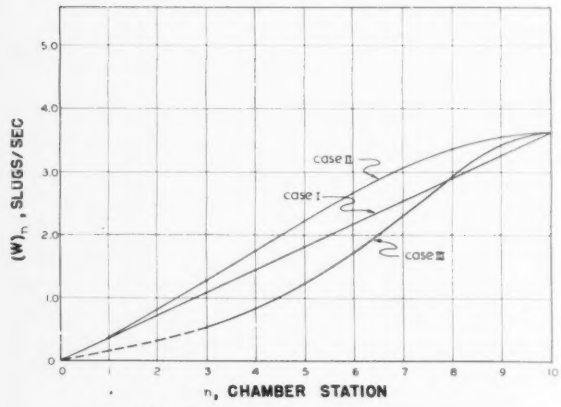

FIG. 2. Total mass of combustion gases.

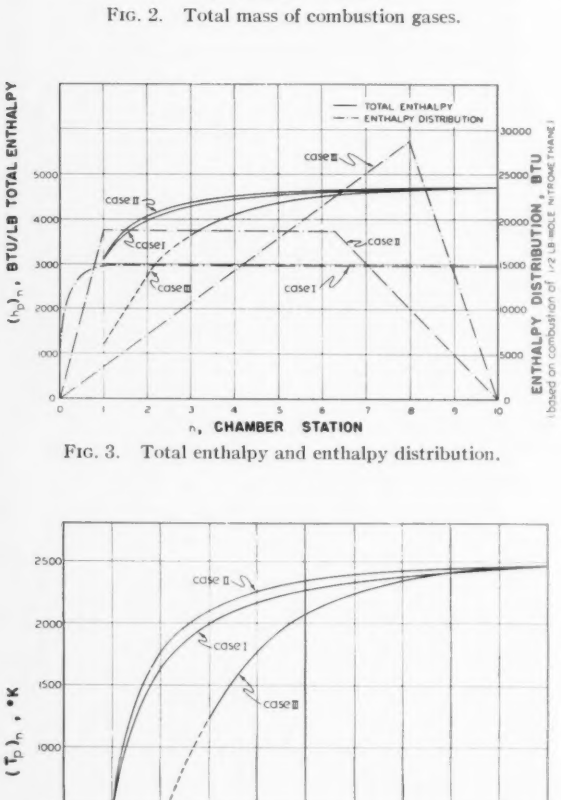

FIG. 3. Total enthalpy and enthalpy distribution.

FIG. 4. Total temperature.

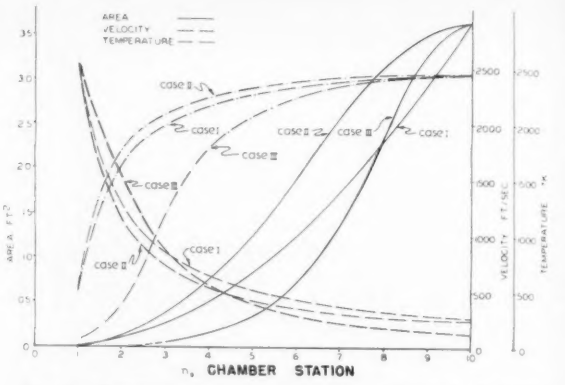

FIG. 5. Constant pressure process p = 43,200 lb./ft.^{2} (300 lb./in.^{2}) (area, velocity, and temperature variation along combustion chamber for cases I, II, and III).

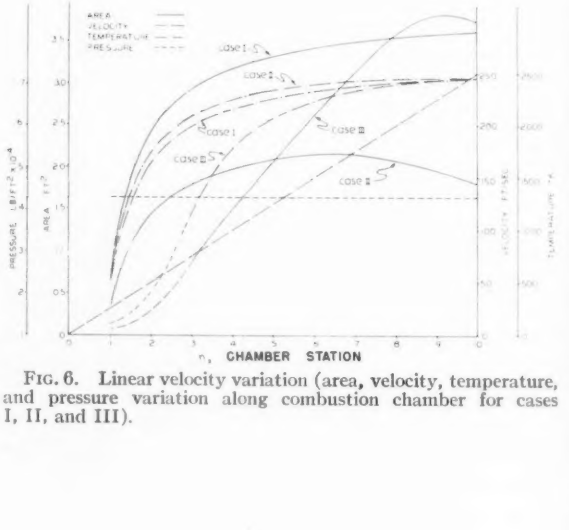

FIG. 6. Linear velocity variation (area, velocity, temperature, and pressure variation along combustion chamber for cases I, II, and III).

FIG. 7. Parabolic velocity variation (area, velocity, temperature, and pressure variation along combustion chamber for cases I, II, and III).

propulsion devices; however, rocket combustion chambers are of primary consideration. The numerical examples included serve to illustrate the results of the calculations and were selected to cover a variety of conditions; they should not be considered comprehensive.

The variation of the significant flow parameters in rocket combustion chambers depends on the manner in which the propellant is introduced as well as on the chemical, aerodynamic and thermodynamic changes. So that a better understanding of these variations may be possible, a simplified but realistic model is developed and the problem is treated as steady and one dimensional.

The model used makes it possible to simulate any desired introduction of the propellant into the combustion chamber. The combustion chamber is divided into an arbitrary number of volume elements (see Fig. 1) and into each of these a prescribed amount of propellant is injected or a prescribed amount of propellant is evaporated and combusted in each of these volume elements.

The particular pattern of injection of the propellant and its availability for combustion in each volume element will determine the variation of total enthalpy along the axis of the combustion chamber. Once this distribution is established, the equations describing the flow and the thermodynamic state allow the determination of the flow-parameter variation along the combustion chamber.

There are four equations available for the determination of the five dependent variables: velocity, pressure, density, temperature, and cross-sectional area. Therefore, one of the variables will be prescribed as a desired function of the axial distance in the combustion chamber. The four equations are: the continuity equation, the momentum equation, the energy equation (radiation and conduction were neglected), and the equation of state.

In the numerical examples presented, it is assumed that the combustion is completed before the gases enter the convergent-divergent nozzle. This is not a necessary assumption in the application of the analysis, but it simplifies the calculations and for this reason it is used in this paper. A monopropellant was chosen for the sample calculations.

The constant pressure, linear velocity variation, parabolic velocity variation, and constant cross-sectional area problems are calculated for each of the three different mass introductions chosen. In each case it is assumed that the heat liberated by combustion in the first volume element of the chamber is used to raise the temperature of the remaining propellant to its boiling point thereby "preparing" it for instantaneous evaporation and combustion. Nitromethane (CH_3NO_2) was chosen as the monopropellant and the chemical kinetic calculations were taken from reference 10. The thrust of the motor was chosen as 25,000 lbs. for all cases. The specific impulse is $I_{sp} = 215$ (lb. force sec./lb. mass) and, therefore, the total mass flow of propellant is $w_N = 3.612$ slugs/sec. Some of the assumptions in reference 10 are: The monopropellant is introduced at 300°K., the combustion chamber is insulated, the products of combustion will expand isentropically to 14.7 psia, chemical equilibrium is maintained to 1,600°K., and the combustion chamber pressure is 300 psia throughout. This last assumption is violated in the example of the constant area process. No iteration was carried out to correct the combustion calculations since the effects of the pressure variation are of second order.

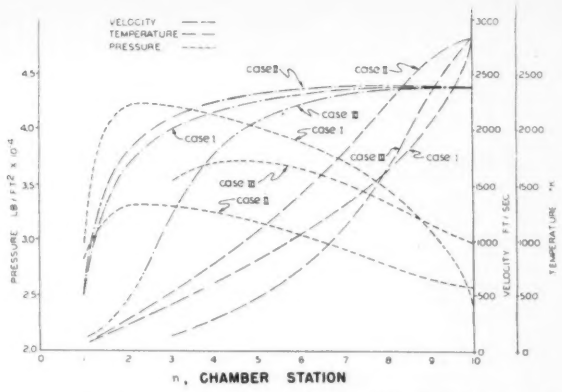

FIG. 8. Constant area process (combustion chamber area = 0.545 ft.²; velocity, temperature, and pressure variation along combustion chamber for cases I, II, and III).

The three cases present various modes of mass "introduction" and energy release along the combustion chamber, as may be seen from Figs. 2 and 3. Fig. 4 shows the variation of the total temperature of the combustion gases. For all examples presented, it was assumed that the temperature at the end of the combustion chamber is equal to the flame temperature. This is valid only for an adiabatic chamber with combustion completed at the "end" of the chamber.

Figs. 5 to 8 present the variations of the flow parameters and the area for Cases I, II, and III (the prescribed conditions are stated on the figures). The values in the first three volume elements were obtained by extrapolation since the charts of reference 10 were not valid in this region. All the results are representative from the fourth volume element on.

The figures show that the variations of the flow parameters and the cross-sectional area distribution can be determined once the desired energy release is prescribed along combustion chambers. These variations are shown to be different from those usually assumed for rocket engines. The results presented should serve as a useful guide for design engineers.

REFERENCES

[1] Ross, C. C., and Datner, P. P., *Combustion Instability in Liquid Propellant Rocket Motors—A Survey*, AGARD, 1953.

[2] Ross, C. C., *Scaling of Liquid Fuel Rocket Combustion Chambers*, AGARD, 1955.

(*Continued on page 47*)

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Take-Off and Landing Distance and Power Requirements of Propeller-Driven STOL Airplanes

It is shown that wing stall can be encountered even though the entire wing is immersed in the propeller slipstream. The effects of wing stall on the power requirements in the transition-speed range and on the take-off and landing distance are illustrated. With the stall under control, the STOL performance becomes primarily a function of the amount of power installed in the airplane.

TWO APPROACHES can be made in seeking STOL performance. On the one hand, use can be made of low wing loadings and high lift devices. On the other, power can be applied to produce lift directly and thus reduce the flying speed. The first case is always limited to some finite minimum speed by wing stall. The second case is limited only by the amount of power the designer wishes to install in the airplane. If sufficient power is used, VTOL performance can be achieved. The power required for the desired STOL performance might become quite high, however, if the wing must be flown through the stall, and experience has shown that, even with the wing completely immersed in the slipstream, stalling can occur in the approach condition. The effect of this stalling on the power requirements and STOL performance and the available means of minimizing this stalling will be reviewed in this paper.

General Considerations

Before examining the problems of power requirements and wing stall, it appears in order to examine some of the factors other than the characteristics of the airplane that may limit STOL performance. Such factors as deceleration during the landing ground run, the normal acceleration in the transition, and the effect of rate of descent on the pilot's ability to fly the proper approach path all have a significant bearing on the STOL performance. The landing distance can conveniently be assumed to be made up of three stages —the approach, transition, and ground run as shown at the top of Fig. 1. The limitations on each can be examined separately.

The author's complete work is still available as IAS Preprint No. 690.

The author is Aeronautical Research Engineer, High-Speed Tunnel Section, Stability Research Division.

Approach Distance

The distance required to descend from a 50-ft. height is determined by the approach angle used. However, it was determined in reference 1 that the maximum approach angle that can be used with consistency decreased with an increase in approach speed and that rate of descent is the determining factor. Although the descents in reference 1 were made with helicopters, it was determined that the limitations on rate of descent were not associated with the characteristics of the helicopter but were established by the ability of the pilot to observe directions and to make corrections quickly enough to maintain the desired approach path.

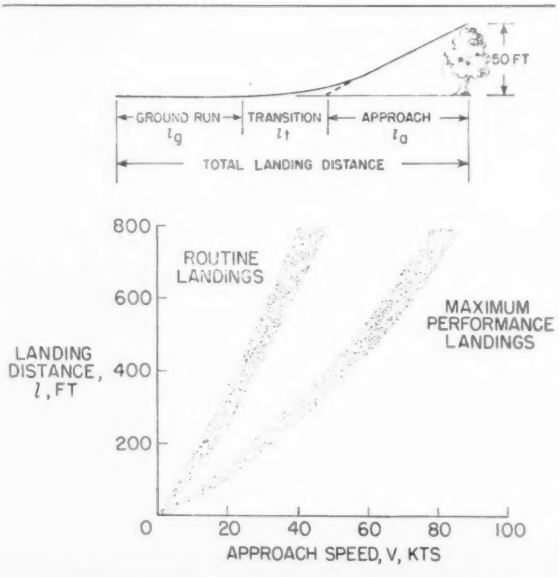

FIG. 1. Landing distance over 50-ft. obstacle.

In general, rates of descent no higher than 500 to 700 ft. per min. appear to be appropriate for more or less routine flying, while rates of descent similar to those experienced in helicopter autorotation (1,000 to 1,500 ft. per min.) might be considered satisfactory for maximum performance landings. For practical purposes, the approach distance then can be expressed as

$$l_a = 5{,}070\ V/V_v$$

where V is the approach velocity in knots, and V_v is the rate of descent in feet per minute.

Transition Distance

The transition distance is a function of the approach speed, approach angle, and the normal acceleration used in the pullout. If we assume a circular-arc transition and let the approach angle be determined by the rate of descent as previously discussed, the transition distance is given by

$$l_t = VV_v/71g\ \Delta n$$

where Δn is the increment of normal acceleration in the transition, measured in g units, and g is the acceleration of gravity.

The shortest transition distance would, of course, be obtained by eliminating the transition entirely and allowing the airplane to contact the ground at the approach angle and rate of descent. This might be considered acceptable for emergency or maximum performance landings if the landing gear were designed for it but would probably not be acceptable for routine flying.

Ground Run

The ground run distance in landing is a function of the velocity at touch-down and the deceleration. We are dealing with airplanes that use an appreciable amount of power in the landing approach. If the power is cut at the instant of touch-down, essentially all of the airplane weight is on the ground and effective braking is immediately available. The maximum deceleration available then is equal to the coefficient of friction that is available, and the landing distance is given by

$$l_g = 1.43V^2/C_fg$$

where C_f is the coefficient of friction.

Although a coefficient of friction of 0.8 to 1.0 (and therefore 0.8g to 1.0g deceleration) can be obtained on dry concrete runways, this would be a rather extreme level to plan on for routine operational use, particularly if passengers are being carried. A deceleration of about 0.3g is a more comfortable and realistic value under these conditions. The stopping distances obtainable at these values of deceleration are plotted in Fig. 4. Still higher decelerations and correspondingly shorter stopping distances could be obtained by the use of reverse propeller pitch. Whether this would be desirable would depend upon the intended use of the airplane.

Total Landing Distance

On the basis of the foregoing observation we can arrive at an estimate of the total landing distance required. Fig. 1 shows the landing distances for routine and maximum performance landings. The maximum performance landings assume a rate of descent of about 1,000 ft. per min., no transition (which would require a specially designed gear, of course), and a stopping deceleration of 0.8g. The routine landing distances assume a rate of descent of about 500 ft. per min., a circular-arc transition with an increment of normal acceleration of 0.1g, and a relatively comfortable stopping deceleration of 0.3g. No allowance has been made in either case, however, for any margin of error by the pilot or for his reaction time in reducing power and applying brakes at touch-down.

It is apparent from these curves that to achieve short landing distances the airplane must be able to fly rather slowly. If the commonly used criterion of a landing distance of 500 ft. is used, it can be seen that the approach speed will probably have to be in the neighborhood of 30 knots for routine flying. If, however, the actual field length is 500 ft. from obstruction to obstruction, allowance will have to be made for the length of the airplane and some reaction time and margin of error on the part of the pilot. The approach speed then would probably have to be down to about 20 or 25 knots for routine flying. Even assuming maximum performance or emergency conditions, the approach speed could probably not exceed 40 or 50 knots.

The limitations on take-off in general do not appear to be as severe as those on landing. There is no limitation on the rate of climb and, with forward facing seats, accelerations of appreciable magnitude could be tolerated. The transition, on the other hand, cannot be avoided; however, the distances involved are not great. In general, it appears that the take-off distances can be at least as short as the landing distances so far as considerations other than the performance of the airplane are concerned. The take-off distance then will be determined primarily by the thrust-weight ratio of the airplane, and with the thrust-weight ratios that will be necessary to obtain short landings there should be little problem in obtaining short take-offs.

Effect of Stall on STOL Performance

With small airplanes low stalling speeds can be obtained by the use of low wing loadings and conventional flaps. Note, however, that we are dealing with the approach speed and not the stalling speed. Even with a Piper Cub it is not considered safe to use approach speeds less than about 50 knots.

With large airplanes it is obviously impractical to attempt to achieve these low speeds by the use of low wing loadings. With large airplanes other consider-

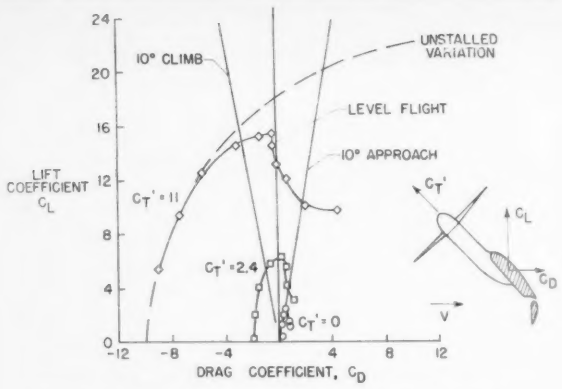

FIG. 2. Effect of thrust and slipstream on lift and drag characteristics.

ations require relatively high wing loadings, and therefore the low approach speeds required can be obtained only with very high lift coefficients which can be obtained only by using power in some form.

These high lift coefficients can be obtained by the proper utilization of propeller thrust and slipstream as shown in Fig. 2. Here the lift-drag polars[2] for several power conditions are shown. At a thrust coefficient of zero, the normal power-off lift-drag polar is obtained. As power is applied and the free-stream velocity is decreased, the diagram expands upward and to the left. At a thrust coefficient of 11 ($C_T{}' = T/qS$), a maximum lift coefficient of 15 is indicated. If the free-stream velocity is reduced to zero, the thrust coefficient and lift and drag coefficients approach infinity because there are still forces present due to the propeller thrust and slipstream.

It is possible then to obtain any desired lift coefficient. The problems that arise are: How much power is required to produce the desired lift coefficient, and can it be obtained at flight conditions of interest without stalling the wing? The designer can exercise some control over the power requirements by varying the propeller size and the wing span. A procedure for calculating the power requirements is presented in reference 3.

The problem of obtaining these high lift coefficients in usable flight conditions is also illustrated in Fig. 2. Note that for steady level flight the propeller thrust and the airplane drag must be in balance. Thus $C_D = 0$ represents steady level flight conditions. As the thrust coefficient is increased, the peak lift coefficient moves from the drag to the thrust side of the diagram, and for level flight at a thrust coefficient of 11 the airplane would be flying in a stalled condition.

A pictorial presentation of the stall is shown in Fig. 3. The unstalled case is shown at the left. The propeller thrust is counterbalanced by the horizontal component of the resultant force vector on the wing, and the vertical components add up to give the total lift. If the wing were stalled, the resultant force vector would be much shorter and the horizontal component would be insufficient to balance the thrust. Under these conditions the angle of attack would have to be increased, which would aggravate the stall, but eventually equilibrium would again be reached as shown by the case on the right. The lift is greatly reduced, however, as a consequence of the separated flow.

The extent of the losses due to stall are illustrated in Fig. 2. For convenience in discussing the figure, lines representing combinations of C_L and C_D that would give 10° climb and 10° approach angles are also shown. It can be seen that in a 10° climb only a small amount of separation shows up at a thrust coefficient of 11. In the approach condition, however, where stalling is encountered, the lift available is only about half of the potential unstalled lift.

The effect of this stalling on the power requirements in climb, level flight, and approach are shown in Fig. 4. These curves are for an assumed airplane weighing 44,000 lbs., with a wing area of 1,100 sq.ft., and using four 20-ft.-diameter propellers, and were computed by the procedure outlined in reference 3. This airplane could hover on about 10,000 hp., and as the speed is increased the power drops off quite rapidly for the unstalled condition.

In a 10° climb, the stall causes only a small increase in the power required in the speed range between 20 and 40 knots. In level flight, the effect of the stall is much more pronounced, and in a 10° approach, it completely changes the character of the curve. If this were a STOL configuration with only 6,000 hp. installed, the minimum approach speed for a 10° approach would be increased from 12 to 60 knots by the stall. This seriously affects the landing distance as shown on Fig. 5.

In Fig. 5 the power has been fixed at 6,000 hp , and the landing and take-off distances have been calculated as a function of gross weight. It can be seen that the airplane could operate as a VTOL machine at 28,000 lbs. but that with only a moderate overload the landing distance jumps to about 1,000 ft. for the stalled case. For the unstalled case, however, the landing distance increases gradually with increase in gross weight. At the previously used gross weight of 44,000 lbs. (power loading of 7.3 lbs. per hp.), the landing distance would be only about 400 ft. Thus we see that, if the stall can be avoided, the landing distance is primarily a function of the gross weight and power installed, and there need by no basic difference between an STOL and a VTOL configuration except power. As would be expected from the previous discussion, the take-off distance is not as seriously affected by the stall.

The discussion up to this point has served to illustrate the effects of the stall and the importance of avoiding or minimizing it. The next question of course is, "What can be done about it?"

STALL CONTROL

Wind-tunnel tests have provided us with some guide posts that point the way toward eliminating or at least reducing the effects of the stall on STOL performance.

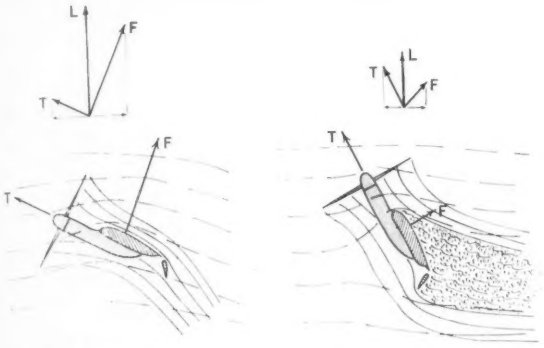

FIG. 3. Schematic representation of effects of flow separation.

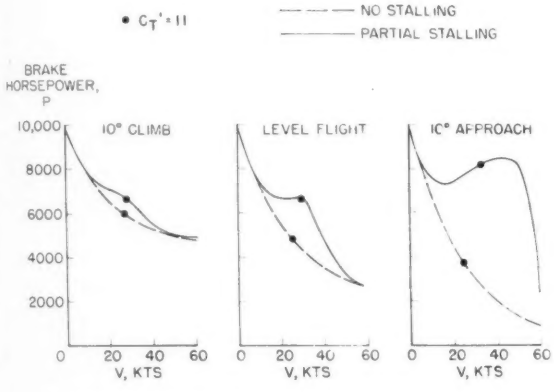

FIG. 4. Effect of wing stall on power required.

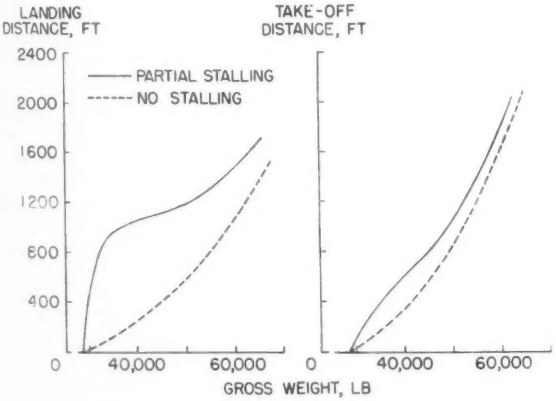

FIG. 5. Effect of wing stall on take-off and landing distance (6,000 hp.).

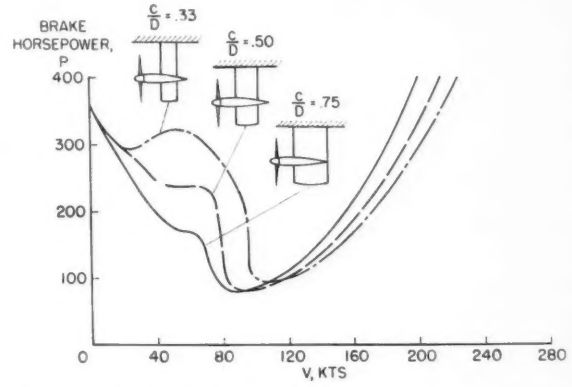

FIG. 6. Effect of changing wing chord on power required with constant weight and propeller diameter.

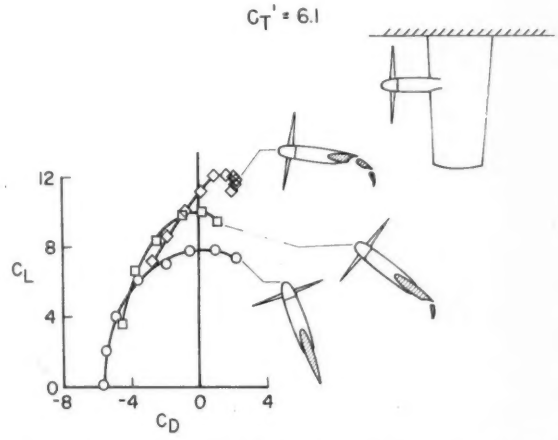

FIG. 7. Effect of wing-flap configuration on lift-drag polars.

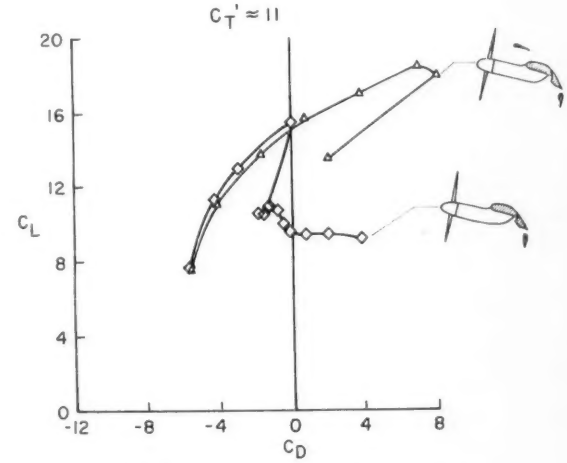

FIG. 8. Effect of slat on lift-drag polars.

One extremely important parameter in this respect is the relative size of the wing and the propellers.

If we were dealing with a VTOL machine, it would be desirable to keep the disc area as large as possible to reduce the power required for vertical take-off. Also to obtain as high a speed as possible, it would be desirable to keep the wing area small. This results in a low ratio of wing chord to propeller diameter and can have serious consequences in the transition or STOL speed range as illustrated in Fig. 6.

The power requirements in Fig. 6 were calculated from model data for an assumed airplane having a gross weight of 2,500 lbs., using two 10-ft.-diameter propellers, and having a wing span of 25 ft. The large increase in power required due to decreasing the wing chord is readily apparent.

There are, however, a number of factors involved in the differences shown. Note that decreasing the wind chord also resulted in increasing the wing loading. These changes in wing loading account for the different velocities (between 75 and 88 knots) at which the power curves drop almost vertically to meet the more familiar power required curves.

The different power levels required in the transition speed range (say 40 knots), however, indicate the increase in severity of the stall as the wing chord is decreased. The trend of the data indicates that, if this idea of decreasing wing area and increasing propeller disc area were carried too far, it might result in the power required in the transition speed range being greater than that required to hover.

The ratio of wing chord to propeller diameter then is observed to be a powerful factor in determining the severity of the stall. These observations are for tilt-wing configurations but would be expected to apply to configurations employing flaps also.

Another means of moderating the effects of the stall would be to use flaps as shown in Fig. 7. Here a semispan wing with one inboard propeller was tested as a tilt wing[3] and with two flap configurations.[4] Note that a considerable portion of the tip of the wing was outside the slipstream. Moving from the tilt wing to the single-flap and then to the double-flap arrangement shows a progressive increase in maximum lift obtained. Here a high thrust coefficient ($C_T' = 6.1$) was chosen in illustrating the trends so as to be on the conservative side. At lower thrust coefficients the advantages of the flapped configurations are even greater.

This points out another difference between tilt-wing and deflected slipstream configurations. With tilt wings the stall is most severe at moderate thrust coefficients. With flapped configurations it is most severe at high thrust coefficients. This would indicate that for airplane designs that are not expected to approach the hovering condition very closely, and therefore not require high thrust coefficients, the use of a flapped rather than a tilt-wing configuration would definitely be preferred.

One modification that can effectively improve the results obtained with a heavily flapped configuration is shown in Fig. 8 (data from reference 2). Here the addition of a large chord leading-edge slat effectively extends the curve well into the approach range of drag coefficients. Note that the slat is placed much higher and farther forward than normal. This configuration was tested in connection with another investigation, and the discovery of its stall control effectiveness was almost accidental. While the optimum size and location of the slat has not been determined, the meager data that do exist (reference 5 and some unpublished data) indicate that the large size and high forward location used here are more effective in controlling the power-on stall than the more conventional slat configurations.

Any discussion of possible means of stall control would not be complete without at least some reference to boundary-layer control. While experimental data on the combined use of boundary-layer control and propeller slipstreams in the range of propeller thrust coefficients of interest here are not available, there appears every reason to believe that either type (suction or blowing) could be effective.

If it is preferred to avoid the added complication of boundary-layer control, however, the designer still has at his command several tools for minimizing stalling. The proper choice of wing size and propeller disc area, the use of flaps—possibly in combination with tilt—and the addition of a slat can all be used or combined to achieve a considerable measure of control over the wing stall. And with the stall under control, the landing distance becomes primarily a function of the amount of power installed in the airplane.

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Aids to Inertial Navigation

The mechanical and natural limitations of inertial systems, methods to overcome these limitations, the problem of inertial platform misalignment, and methods for platform stabilization are discussed.

In the field of self-contained navigational systems, inertial systems play a significant role. Their advantages are many. They possess the capability of accurately determining the position of a moving vehicle without reference to any landmarks, to any magnetic fields, or to any radiation fields.

These systems, however, have both mechanical and natural limitations. In this paper, it is the intent of the authors to discuss certain of these limitations, and to indicate some practical methods of "aiding" the system performance in order to provide a coherent total design.

Properties of Inertial Systems

Let us consider some of the properties of inertial systems. One distinguishing property of such systems is their method of sensing present position. Our first illustration (Fig. 1) shows how each gravitational vector is uniquely associated with a particular position on the surface of the earth.

Conversely, every point on the earth's surface may be associated with the angular or directional coordinates of the vector. It will be recognized that in precisely this manner, through the mechanism of the spherical stretch map, points on the earth's surface are identified by the classical navigator. It should be noted that these geodetic coordinates of latitude and longitude are independent of linear measurements conducted on the surface of the earth and, further, that the coordinates—i.e., latitude and longitude—of any point may be determined solely by an angular measurement—viz., the direction of the gravitational vector observed at that point.

A diagram of the basic building blocks of an inertial system is shown in Fig. 2.

The heart of today's inertial system lies in its accelerometers, supported by a stabilized platform whose space orientation is slaved to that of its reference gyroscopes. The stable platform is isolated from craft

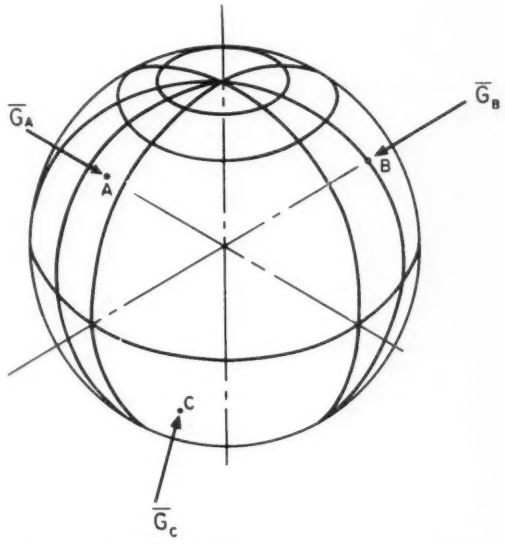

Fig. 1. Relationship of gravitational vector and points on surface of the earth.

angular motions by mounting it on gimbals, involving a varying number of rotational axes, each of which represents a degree of freedom.

Accelerations are sensed and doubly-integrated to derive positional information with subsequent feedback to the inertial reference in order to isolate the effect of gravity from linear accelerations.

The relation of these elements is perhaps best understood by considering a fundamental physical

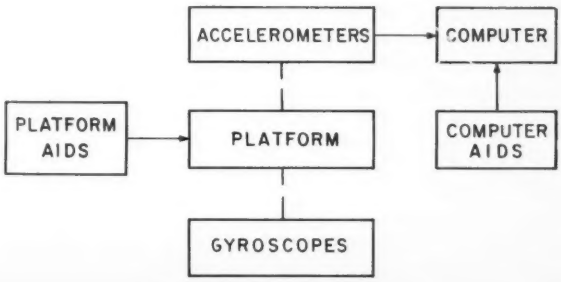

Fig. 2. Basic inertial system.

This paper is available as IAS Preprint No. 737.

The authors are Chief, Missile Guidance and Controls, and Assistant Chief, Guidance and Controls, respectively.

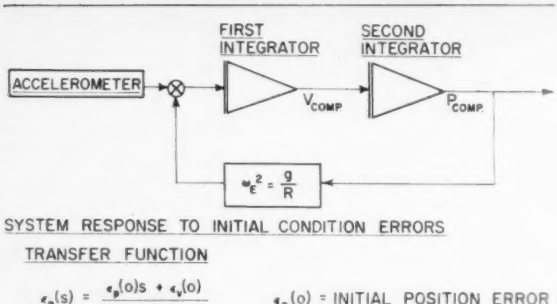

FIG. 3. Undamped inertial computer.

property of inertial systems. This property is commonly known as the "Schuler Pendulum."

In the simple perfect undamped inertial system, if no error is introduced, the system will always provide an accurate solution to navigational problems. The system solution to the navigational problem, however, is not unique. If an error of position or velocity is introduced into the perfect system, this error will be perpetuated in the form of an oscillating error in velocity and position as shown in Fig. 3. This oscillation is similar to the oscillation of a pendulum whose length equals the earth's radius; its characteristic natural period, determined by gravity and the effective pendulum length, is 84.4 min.

It is easy to see that a natural limitation is thus imposed on the unaided inertial system and that system accuracy is necessarily affected by perpetuation of the oscillating error. We shall discuss later computer aids which will allow the damping of the Schuler pendulum and will thus establish a unique system solution to the navigational problem.

In the ordinary and more elementary inertial system design, gyroscopes serve alone as the platform stabilization reference. Initially aligned to some known reference, they are continuously rotated in inertial space in accord with the angular velocity of the adopted coordinate system. Any coordinate system error would introduce corresponding inaccuracy in position indication.

In any practical inertial system, imperfections in gyros, accelerometers, or their alignment can result in measurable errors being introduced into the system. Errors resulting from such imperfections are resolved as pitch errors, roll errors, or heading errors. These are platform errors and exist because of man's inability to design and fabricate elements to the required precision.

A pitch or roll misalignment of 1 min. of arc corresponds to a direct positional error of 1 nautical mile on the earth's surface. Fig. 4 shows how a heading misalignment produces a consistently increasing positional error which increases with the distance traveled from the point where the error occurred. A heading misalignment of 1 min of arc corresponds to an error rate of 0.66 miles per thousand miles traveled.

It can be readily seen that platform misalignment caused by mechanical limitations of the inertial system may become a major source of system error.

For example, gyroscopes whose drift rate is as low as 0.01° per hour can permit an error growth at a rate of almost 1 m.p.h., quite apart from any misalignments which were permitted to exist prior to initial system operation. Even this precision may not be sufficient to meet accuracy requirements in some long-range operations regardless of perfection in the remainder of the system.

Insofar as initial computer settings and initial alignment of the stable reference are concerned, little difficulty is encountered in ground-based systems, where extensive surveys and fixed references may be employed to yield almost any practical desired accuracy. However, such facility is not present in systems operated from moving bases such as ships at sea or air-borne aircraft, and accuracy specifications may in this event prove too demanding to be met by conventional concepts of stable platform mechanization and system alignment. In addition, some ground-based systems which must be placed into action on short notice do not permit sufficient time for satisfactory preflight operations.

Integrator response presents still another problem in the computational aspect of inertial navigation. Here, any inaccuracy is immediately reflected in an equivalent error of integration, which continues to be propagated within the undamped system in its characteristic 84-min. oscillation. This can be particularly offensive in a total coordinate computation, in which integrator range must be spread over that of the necessary flight range. Most approaches are confronted with the difficulty which is encountered in accelerometer design —that of achieving both wide range and high sensitivity in an analog device.

UTILIZATION OF SYSTEM AIDS

It is evident that the unaided inertial system may easily prove unable to perform satisfactorily within

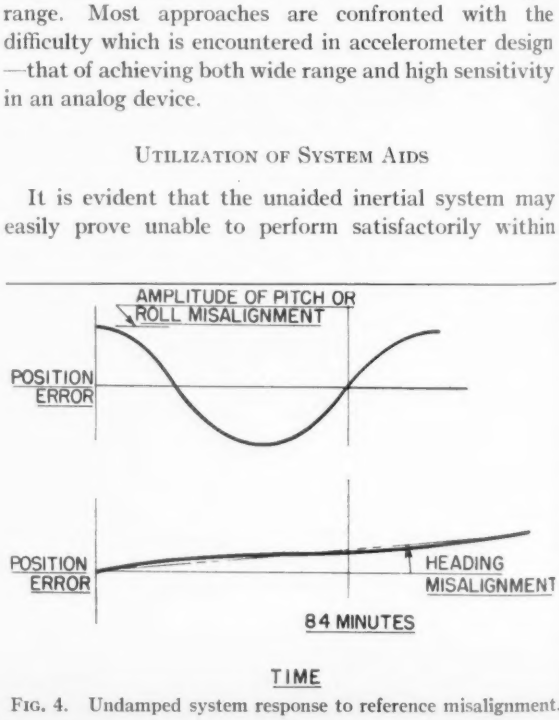

FIG. 4. Undamped system response to reference misalignment.

operational restrictions and ranges associated with a number of applications in which it could otherwise serve to real advantage. To the designer confronted with this situation who desires to retain the advantages of inertial navigation, several alternatives are at once apparent. The first is to proceed with a simple inertial system in the hopeful belief that eventual development of acceptable accurate production components will be possible within the allotted time span. A second and more conservative course involves augmenting the basic system in such a manner as to eliminate its significant limitations as a result of component error and at the same time to escape the risks involved in expecting results too soon in difficult and uncertain development areas.

Velocity Damping

The utilization of an independent source of velocity information for improving inertial navigation system performance through the damping of dynamic errors is evident. Let us consider three modes of utilizing velocity information.

We may process the independent velocity information in such a manner that it may be inserted into the computer as a direct correction to the computed linear velocity; a derived correction to the measure of linear acceleration; or a derived correction to the computed position.

The mathematical equivalence of these three approaches has been established for linear filter design. Because of this equivalence and the directness of the mode wherein the auxiliary velocity information is used to correct the computed velocity, this mode will be used as a basis of further description. A general functional diagram is given in Fig. 5. The conditions which determine the finalized filter design for any particular system are: the simplicity of mechanization desired; the character of the noise associated with the measurement of velocity; and the desired performance.

Generally the desired performance is damping of the 84-min. oscillation associated with the initial conditions and attenuation of the effects of noise in the accelerometer-computer loop. The complexity of the velocity filter is usually restricted to first-order operations and not more than two parameters. The selection of the optimum magnitude of these parameters is determined by the desired rapidity of damping and the nature of the velocity measurement. The current methods of velocity measurement are by Doppler shift in radar echoes and by true airspeed. In the latter approach, wind variations must be lumped with other velocity noise for purposes of determining the filter parameters.

Velocity damping removes only errors in position and velocity associated with the 84.4-min. oscillations.

Fig. 6 summarizes in transform notation the effect of velocity damping on computer indications.

Fig. 7 further illustrates the fact that velocity damping does not correct errors due to platform misalignment.

We have described methods for overcoming a natural limitation of the inertial system imposed by the characteristic 84-min. oscillation. Now we turn to methods for overcoming the mechanical limitations of the inertial system.

Automatic Star Tracking

When operational conditions do not permit accurate platform alignment prior to take-off, and when available gyroscopes can be expected to allow excessive drift of the stable platform, additional equipment to correct the stable platform is necessary.

SIMPLIFIED TRANSFER FUNCTION

$$\epsilon_p(s) = \frac{\epsilon_p(0)s + \epsilon_v(0) + Ks^2N(s)}{s^2 + Ks\omega_E^2 + \omega_E^2}$$

SYSTEM RESPONSE TO INITIAL CONDITION ERRORS

$$\epsilon_p(t) = e^{-\alpha t}\left\{\epsilon_p(0)\left[\cos\beta t - \frac{\alpha}{\beta}\sin\beta t\right] + \epsilon_v(0)\frac{\sin\beta t}{\beta}\right\} + \epsilon_N$$

WHERE

K = A FILTER PARAMETER

$\alpha = \frac{K\omega_E^2}{2}$

$\beta = \sqrt{\omega_E^2 - \alpha^2}$

$N(s)$ = VELOCITY NOISE FUNCTION

ϵ_N = NOISE FORCED ERROR

FIG. 6. Velocity-damped inertial computer.

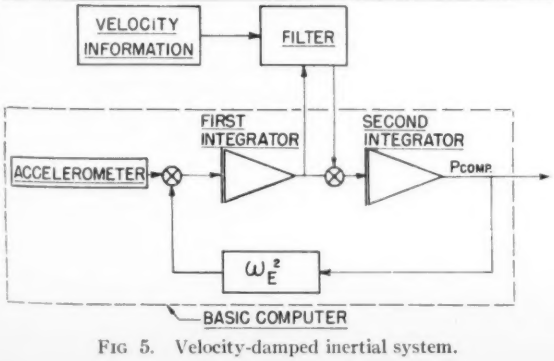

FIG 5. Velocity-damped inertial system.

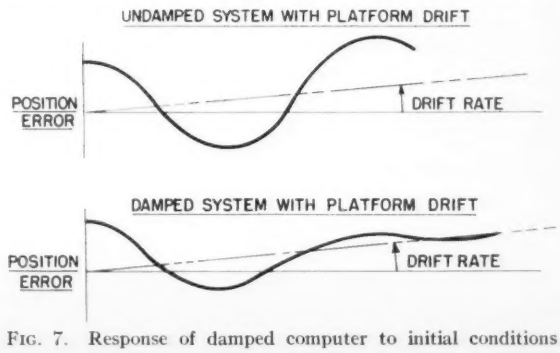

FIG. 7. Response of damped computer to initial conditions.

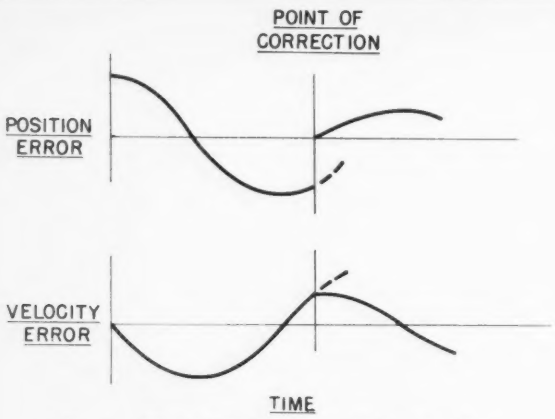

FIG. 8. Effect of single check-point incorporation.

To meet this problem, one or more automatic star trackers can be used in connection with the gyro-stabilized platform to establish the platform space orientation.

In operation, this utilization of star tracking provides signals to the gyroscopes which serve to correct their angular position to inertial space. The stabilized platform continues to operate just as it does in the basic inertial system with the exception that its performance is enhanced; gyroscope drift is eliminated in effect as are misalignments due to severe launch shocks and to poor initial conditions such as may result from inexact knowledge of the launch site coordinates.

During any absence of star tracking information, the gyro-stabilized platform performs just as it would have in any unmonitored system. Star tracking can be initiated anew after periods of cloud cover within limits of the design parameters of the system such as telescope field size and expected drift rates of the unmonitored platform.

The design of tracking equipment for inertial systems presents problems which are met by the designer of all types of tracking systems. Let us examine, however, the problems of optical tracking of celestial bodies.

Tracking system design is first dictated by the class of celestial bodies which is to be used to provide "fixes" on the inertial coordinate system, the time relationship of those bodies to the coordinate system, the desired total field of view, the size of the search field which must be covered, and the time allowed to cover this field.

The class of trackable bodies will usually be determined on the basis of the image properties, size, ease of pointing computations, and the character of background noise levels. The time variation within the adopted coordinate system of the vectors which represent the celestial bodies must, of course, be considered in computation of the ideal, or reference, pointing of the tracking telescope. While the computations necessary to resolve the tracker angles into the platform coordinate system may prove complex, if desired they can be performed on the ground in advance of take-off as well as while in the air.

It should be noted that absolute-time information will be required for an inertial system utilizing celestial tracking, while an "unaided" system could operate with consideration only of the relative time from take-off.

The total angular coverage of which the tracker must be capable in its various pointings relates to the angular distance which it must provide between the celestial vectors which are to be used to correct the angular position and velocity of the reference gyroscopes.

Search and tracking frequencies are based upon the search field size, which must be large enough to include anticipated stable platform misalignments caused by initial error as well as drift between take-off and the inception of tracking. Search and tracking frequencies are also based upon bandwidth considerations related to a usable signal-to-noise ratio. Design of the tracker optics and sensing system are additional factors.

Check-Point Incorporation

Errors from any source may be overcome to a degree by incorporation of check-point information. This is especially true in piloted aircraft applications in which the crew can be of assistance because of its obvious direct relationship to the prime navigational output. Search radar and visual systems have been employed in this respect, the former for its advantage of area coverage, the latter for relative definition and precision. Of course, some reasonable distribution of checkpoints must exist in or near the area where accuracy is of interest if useful information is to be derived.

It is possible to automatize the check-point operation. The fashion in which check-point information usually is introduced to the basic inertial computer to effect the necessary correction is quite elementary, and its effect is illustrated in Fig. 8. As shown, residual velocity error, unaffected by correction of observed position error, is left to propagate a new but not larger error. Thus, a series of check-point observations at suitable intervals can lead at each step to a further reduction of both position and velocity uncertainty, as shown in Fig. 9.

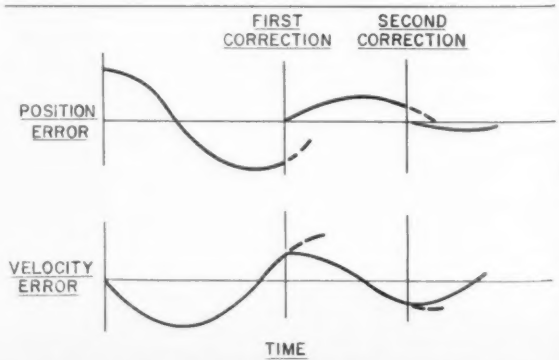

FIG. 9. Effect of repeated check-point incorporation

These corrections, when applied specifically to the computer, permit any reference misalignment to continue as a source of position error. Other and somewhat more complex approaches to check-point correction which affect reference as well as computer alignment are feasible.

Air-borne radar, tracking a beacon whose position is known accurately, can provide a rapid reduction of errors in both position and velocity; this essentially continuous form of check-point incorporation can be performed equally well with interchanged location of tracker and beacon if a communication link is added to the system. Both velocity and position corrections are affected, with time constants chosen on the basis of a compromise between the desire for rapid decay of the error and the necessity to avoid unpleasant effects of tracking noise. When the beacon can be tracked at short range, an appreciable increase in precision can be achieved.

A final method of check-point incorporation involves the use of the hand-held sextant—a procedure familiar to any Air Force or Navy navigator. If the direction of the vertical is assumed to be known, as well as an accurate indication of time, the "shooting" of stars can establish local position.

Combining System Aids

To this point, the discussion has been concerned with the effects of individual techniques for aiding the inertial system. It has been shown that some of these schemes correct the computer, while others secure proper platform orientation; in some cases, either the computer or the platform may be aided, depending upon the manner in which the auxiliary information is introduced into the basic system.

This is accomplished through a combination of two or more of the possibilities already enumerated. For example, the platform orientation could be corrected or improved by radar check-point with the computer employing velocity damping. The combination of star tracking for more exact platform orientation with radar - check-point corrections for the computer is also possible. Highly satisfactory results could be obtained by combining star tracking and velocity damping. The effect of the tracking in this case would be to ensure that the computer is damped to the proper reference so that the computations would be not merely nonoscillating but actually correct.

It is important to note that inertial navigation systems are no mere mathematical concepts. They come in all sizes and shapes, with accuracies to match. Every type of aiding scheme discussed here either is a part of an existing system or has at least been flight-demonstrated. Star tracking is as feasible in daylight and twilight hours as in the dark of night; check-points can be used for computer correction. Velocity damping works as theory indicates it should. Some systems use single aids, some apply combinations, and others get along with no aids at all. Through the use of appropriate aids, the state of the art is such that an inertial navigation system either has been built or could be designed to meet any reasonable set of requirements.

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Combustion Instability of Rocket Motors *(Continued from page 37)*

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1958 NATIONAL MIDWESTERN MISSILES MEETING

St Louis is the location of the National Midwestern Missiles Meeting scheduled for May 12–14, 1958, at the Chase Hotel. The St. Louis Section will be host and, together with the New York office, is busy making advance arrangements and organizing the program of technical sessions. Those who wish to contribute to the Missiles theme may send abstracts of papers to the IAS Secretary, 2 East 64th Street, New York 21, N.Y.

Harold Klein
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An Aerodynamic Screen for Jet Engines

Flow phenomena giving rise to material pickup from aircraft runways, flow characteristics of the "blowaway jet," and test results on the working device are described. Data are given regarding the necessary air quantities and pressures.

SYMBOLS

d	= diameter of throat of blowaway jet orifice
D_i	= inlet diameter
p_0	= ambient pressure
P_{tj}	= pressure applied to blowaway jet nozzle
V_i	= velocity of air entering inlet
V_0	= wind speed approaching inlet
V_T	= terminal velocity of particles
W_i	= weight of air per unit time entering inlet
W_j	= weight of air per unit time expelled through blowaway jet
Z_j	= elevation of blowaway jet nozzle
Z_i	= centerline height of inlet
β	= depression angle of nozzle below horizontal
ρ_0	= ambient density
ρ_j	= jet air nominal density; density at jet temperature and ambient pressure
ω_0	= vorticity of air in stream approaching inlet

THE POSSIBILITY of a jet engine incurring damage by aspirating pebbles, metal particles, mud, slush, or other runway debris is an obvious danger to any airplane engine breathing large quantities of air. Available information indicates that roughly half of all jet engines removed from aircraft for repairs are removed because of damage by foreign material and that the majority of jet engines removed for whatever cause are found on inspection to have suffered damage as the result of the entrance of foreign material into the engines. Such foreign materials may be items left by personnel, thrown in by nose wheels, or picked up with the aspirated air. A breakdown among these sources has not been well established, but it is the elimination of the last source, which is known to be important, that is the subject matter of this paper.

The prevention of foreign material from entering engines has been the source of considerable activity and some controversy. A large fraction of present jet airplanes use metallic screens. Such screens involve performance penalties and to some extent introduce icing and structural failure dangers of their own. With retractable screens, retention of the aspirated material has also been a problem. Steps have been taken to sweep runways with powerful vacuum cleaners. Since jet-engine overhaul is expensive and since both economics and safety are involved, the prevention of engine damage by foreign material is important.

EARLY TESTS

The DC-8 jet transport, in common with many other aircraft, has large turbojet engines comparatively close to the ground. The possibility that the engines might suck up loose material from the runways was recognized early in the design of the DC-8 airplane. In order to investigate the problem, a series of small-scale tests was conducted in 1953.

An industrial vacuum cleaner was used with a 1-in. diameter inlet. For the simple case of zero wind speed and a smooth ground plane, reference 1 describes these tests in which measurements were taken of the extent to which particles were aspirated. It was found possible to characterize the particle by a terminal falling speed, regardless of its physical shape or composition. The data obtained and plotted as the line on Fig. 1 show the centerline heights in diameters as a function of the ratio of particle terminal speed to inlet air speed for the threshold of particle aspiration. For example, from this figure, an inlet 2.53 diameters above the ground (which corresponds to the JT3C inboard engines on the DC-8) would suck up particles with ratios of particle terminal velocity to inlet velocity of less than 0.009. If the inlet velocity is taken as some definite value, then in dealing with material of a certain density, say sand or pebbles, it is also possible to add a scale of particle diameter. This has been done in Fig. 1 using the DC-8 inlet velocity.

This work is an abridgment by the author of a comprehensive paper of the same title obtainable as IAS Preprint No. 676.

The author is Aerodynamics Design Specialist, Santa Monica Division.

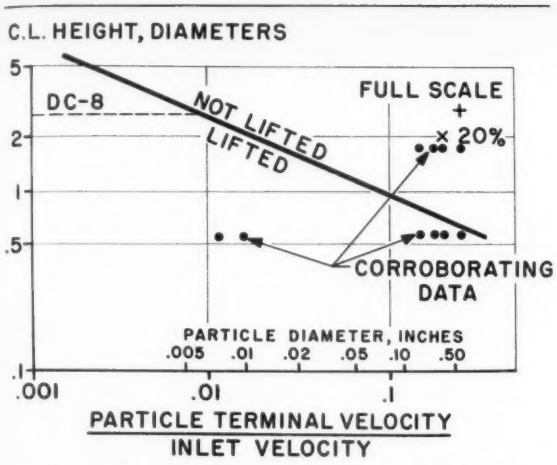


FIG. 1. Comparison of experimental data on turbojet inlet particle aspiration.

For the above example one would expect only sand less than 0.006 in. in diameter to be aspirated. This was supported by all the full-scale tests performed by engine manufacturers and quoted in reference 1. These corroborating data are shown on Fig. 1. It was recognized at the time that this conclusion applied only in the absence of wind and that wind conditions aggravated the pickup of material. It was further recognized that the pickup of material was associated with a rotating type of vortex flow beneath the inlet. The difficulties associated with running tests under various wind conditions precluded running systematic tests at that time.

In 1955 the NACA reported a series of full-scale engine tests run out of doors at the Lewis Flight Propulsion Laboratory.[2] These tests indicated that under quiescent conditions essentially no material was aspirated, in agreement with the conclusion from the threshold line of Fig. 1. Under wind conditions between 1 and 17 m.p.h., however, pebbles estimated as 1/2 in. in diameter were sucked into the inlet in considerable number. This sucking up was associated with a vortex which was visible because of condensation and which appeared in front of the inlet. The vortex seemed to suck up any pebbles which were prevented from rolling by a rough ground surface. The NACA data point is shown as the plus sign on Fig. 1. Thus the full-scale tests showed that under certain wind conditions the engine sucked up particles very much larger than predicted from the quiescent threshold line deduced from model tests.

A second series of tests was then conducted in a Douglas Santa Monica test facility. A 20 per cent scale model (6 in. inlet diameter) was constructed and coupled to a large blower. This facility was capable of achieving full-scale inlet velocities. In order to maintain a strong consistent vortex, it was found expedient to construct an apparatus which would give a controllable rotation. A fan was used in a circular baffle to ensure a prerotation in the air approaching the inlet. It was found that the circular baffle was not necessary if the fan were properly positioned. This test led to the following conclusions:

(1) The vortex noted during the full-scale tests of reference 2 could be readily reproduced and was due primarily to rotation in the air stream, because of wind conditions remote from the inlet, and to the updraft caused by the inlet. Both were extremely important, and increasing either greatly intensified the vortex. The effects of the type of ground surface and boundary layer on vortex formation were relatively unimportant. This last was proved by replacing the ground plane by a second "image" inlet. The resulting vortex seemed to be, in all respects, the same as the vortex from a ground plane.

(2) The measures for alleviation tried at the time of the 20 per cent tests were ineffective. These included raking the inlet, adding a "bib," using an elongated inlet, and trying several other configurations designed to fend off the pebbles. The vortex and pebbles both displayed a singular agility in dodging any obstacles.

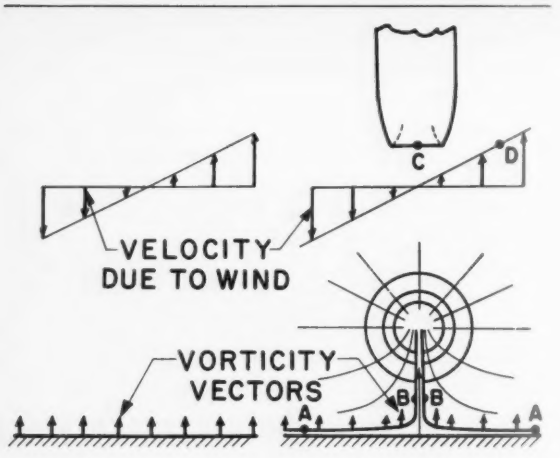
(3) In agreement with the tests of reference 2, it was found that large pebbles could be aspirated by the DC-8 engines when the vortex was present. This is indicated by the "x" shown on Fig. 1.

Following these tests, an additional remedy was considered which consisted of a fan slipstream designed to blow away the vortex. This stream would take advantage of the fact that a linear vortex induces no velocity on itself, however large the velocities induced elsewhere. It was reasoned then that even a small velocity, however induced, should suffice to blow away the vortex. The difficulty envisioned at that time (this difficulty was later borne out for a horizontal stream) was that, unless the air stream was very large in diameter, the vortex would simply bend around the fan slipstream as it did around the other obstacles and appear elsewhere. Because of this envisioned difficulty, no further tests were conducted for approximately 1 year.

In the summer of 1956, a 40 per cent inlet model which had been used for inlet performance tests became available for additional pebble pickup tests. It was decided then to run some tests including whatever new remedies had been suggested since the 20 per cent scale tests. These included a stream of air from a fan. It was suggested that a jet of air also be tried because it could more readily be provided on the aircraft. The 40 per cent scale tests were begun in July, 1956, and the findings of this test are the main subject of this paper.

VORTEX FORMATION

The phenomenon of vortex formation is a well-known and striking occurrence in nature. The formation of a vortex in a draining bathtub for example is a familiar sight. In the ordinary operation of propeller-driven aircraft, the formation of a visible vortex over a wet runway or in damp weather is a fairly com-



a. NO INLET, UNIFORM VORTICITY

b. INLET PRESENT, CONCENTRATED VORTICITY

FIG. 2. Flow phenomena giving rise to a vortex.

mon occurrence. A study of meteorological journals and textbooks indicated that the formation of tornadoes, dust devils, and fire whirlwinds had been observed and studied by many investigators (for example, references 3 and 4).

The cause of the formation of a vortex is fairly well understood. The explanation given here was chosen to facilitate understanding the remedy developed. Consider an inlet which is mounted above a flat ground as in Fig. 2. Suppose a nonuniform wind is blowing with a velocity whose magnitude is indicated in Fig. 2a. Such a velocity gradient can be caused by the wind blowing past surrounding buildings or a grove of trees—or by some other cause. However caused, the constant velocity gradient assumed here for simplicity gives a uniform vorticity expressed by

$$\omega_0 = \text{velocity gradient}$$

This vorticity vector is directed vertically upward as in Fig. 2a which means that the local elements of air on the ground are each individually rotating about a vertical axis with the same angular velocity. The presence of the inlet of itself creates a flow pattern similar to that in Fig. 2b. The heavy stream tube shown goes from a very wide cross-section area close to the ground to a very narrow one above the ground. It is well known[5] that the product of vorticity and stream-tube area is a constant in any given stream tube. This product is termed the circulation. It follows that this product is constant between the sections AA and BB. It follows also that the vorticity at BB is enormously increased above the undisturbed value ω_0 prevailing at AA since the area of BB is extremely small compared to that at AA. This increase is then due to the updraft created by the inlet. It is this increase in vorticity which constitutes the concentrated vortex observed. From this example, we generalize that the following three requirements must be met in order to form a vortex:

(1) There must be a circulation in the fluid under consideration. (It should be pointed out that the circulation produced by the rotation of the earth is completely negligible here.)

(2) A concentration of the vorticity must result from the flow pattern. A suitable method of such concentration is an updraft away from a surface. This updraft is caused by buoyant forces in the case of dust devils, by the inlet in the case of a jet-engine or wind-tunnel intake, and by the drain (creating a downdraft) in the case of the draining bathtub.

(3) A stagnation point is also required for a stationary vortex. This is required inasmuch as the vortex otherwise would not remain stationary but would move away with the fluid.

If any one of these requirements is not met, the vortex will not form. For example, in Fig. 2b, if the inlet were centered at D instead of C, the high mean velocity could prevent the formation of a stationary vortex there if it prevented a stagnation point below the inlet.

Behavior of a Downward Directed Jet

The remedy developed here is called the "blowaway jet." In order to see how it operates, it is well to consider first a few characteristics common to streams of air induced by fans, by blowers, or by high-pressure jets of air. Experiment, as well as theory, indicates that such a jet gradually mixes with its surroundings and slows down. Further, the velocity on the jet axis is found to vary approximately inversely as the distance as one moves axially downstream along the jet. These characteristics are indicated in Fig. 3a. Notice that, if mixing did not take place, no slowing down would be observed and the jet would continue unattenuated. This is in contrast to a simple source or sink whose streamlines spread in all directions even without any mixing and whose velocities vary inversely as the distance squared. This difference is illustrated in Figs. 3a and 3b and leads to the conclusion that in certain regions even a small jet will locally induce larger velocities than a sink.

Another characteristic of a jet that is pertinent is the fact that a jet of air directed onto a plane spreads radially in all directions in the manner suggested in Figs. 3c and 3d. For the purpose here the following is to be noted. Neglecting mixing the velocity is constant along the free streamline AB. Thus the velocity directed radially outward is constant, and the height BC of the jet diminishes as the inverse of the radius.

The pertinent facts of a jet directed at a plane are then the following:

(1) The jet influence penetrates a considerable distance compared to a sink.

(2) The jet spreads very thinly on the plane, and the radial velocity is high until mixing effects diminish it in the manner suggested in Fig. 3d.

The jet directed at a plane is the crux of the blowaway jet, and, since applicable data were not known, a series of tests was run on jets of this type. Some of these data along with a dimensional analysis of the problem have been given in reference 8.

The Blowaway Jet Basic Principle

The principle of the blowaway jet then consists of the following. A jet of air induced by a fan or by a high-pressure air source is directed downward below the inlet. This jet of air carries to the ground and spreads on the ground in all directions in the manner previously described. The velocities induced at the ground by even a relatively small jet are sufficient to overpower any inward radial velocity induced by the large inlet. This is by virtue of the previously stated fact that the jet velocities decay as $1/R$, whereas the inlet-induced velocities decay as $1/R^2$. Thus the jet-induced velocities are sufficient to prevent the concentration of vorticity leading to the vortex and to prevent any vortex from attaching below the inlet. This was found to prevent completely any material being sucked into the inlet.

Test Arrangement

The test arrangement in the photograph of Fig. 4 was set up in the Santa Monica wind-tunnel facility. A 40 per cent scale model of the DC-8 inlet was positioned a distance above the ground in accordance with the DC-8 inboard nacelle. The inlet was connected to a laboratory blower that could obtain full-scale inlet velocities. In order to achieve a consistent, powerful vortex it was found desirable to use two opposed blowers to create a shear flow. The exact positioning of these blowers was important in order to produce a stable vortex for observations. The winds imposed by the blowers were not appreciably larger than natural winds frequently encountered. This arrangement gave a reasonably controllable vorticity which sufficed to create a strong vortex when the inlet was absorbing large quantities of air. Below the inlet a pipe was arranged from the laboratory air supply as shown in Fig. 4. This pipe could be rotated about its axis. Drilled pipe plugs of various sizes could be inserted into the pipe tee, and the pressure could be controlled by the throttle valve and measured by the gage. This provided a controllable jet whose direction, size, and pressure could be varied. Tests were run with a series of orifice sizes, air pressures, depression angles, and with various other conditions to be discussed later.

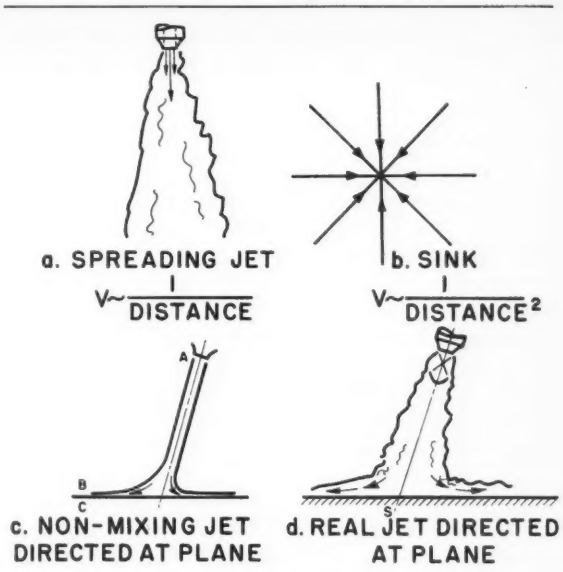


Fig. 3. Some features of a jet directed at a plane.

Test Results

Tests were run with the described equipment in the following manner. The flow into the inlet was held at such a value as to give full-scale inlet velocities. The ground surface was provided by a plywood board on which various materials could be placed. The best materials to illustrate the phenomenon involved were found to be water spread over the surface of the plywood, supplemented by small metal parts or pebbles scattered on the plywood. Fig. 4 shows the vortex formation over a dampened floor. Tests were run with each orifice configuration by throttling down the pressure to such a value that the vortex was just dissipated. Higher pressures blew material outward from beneath the inlets somewhat more violently, and lower pressures permitted the vortex to reappear occasionally.

A dimensional analysis of the problem given in reference 8 led to the result shown in the equation below. The parameter on the left represents the fraction of the inlet air required to dissipate the vortex. The first three parameters on the right represent the conditions of the inlet and its surroundings. All the parameters on the right of the equation below were held at the values of Table 1 and the pressure valve regulated to provide the required W_j/W_i and accompanying pressure ratio. This gave W_j/W_i for specified

$$\left(\frac{W_j}{W_i}\right) = \phi\left[\frac{Z_i}{D_i}, \frac{\omega_0 D_i}{V_i}, \frac{V_0}{V_i}, \frac{Z_j}{D_i}, \beta, \frac{P_{t_j}}{p_0}, \frac{\rho_j}{\rho_0}\right]$$

Required airflow ratio	Inlet height	Approach vorticity	Approach velocity	Blow-away jet height	Depression angle	Jet total pressure	Density ratio
	Inlet configuration and ambient condition			Jet considerations			

TABLE 1
Independent Variable Values Maintained During Tests
(40 Per Cent Scale Model Data for Fig. 5)

Dimensional Values

Inlet Diam.	Inlet Height	Ambient Density	Wind Speed	Nozzle Height	Nozzle Shape	Nozzle Gage Pressure	Nozzle Diam.	Depression Angle	Jet Density
D_i	Z_i	ρ_0*	V_0	Z_j		$P_{tj} - p_0$	d	β	ρ_j*
ft.	ft.	slugs/cu.ft.	ft./sec.	in.		lbs./sq.in.	in.	deg.	slugs/cu.ft.
1.01	2.57	0.00238	0	20.8	convergent	30 to 175	0.08 to 0.33	70	0.00238

Dimensionless Ratios

Inlet Ht./Diam.	Vorticity Ratio	Wind / Inlet (velocity ratio)	Nozzle Ht./Diam.	Depression Angle	Density Ratio
Z_i/D_i	$(\omega_0 D_i/V_i)$†	V_0/V_i	Z_j/D_i	β	ρ_j/ρ_0
2.53	0.015	0	1.7	70°	1.0

* These quantities were taken as standard values.
† This measurement was taken at 3 in. above ground and is believed to be only approximate.

values of the independent variables. By changing orifices, a plot against P_{tj}/p_0 was possible.

The observed data are given in Fig. 5. The ordinate represents the airflow expended through the orifice as a fraction of inlet airflow, the abscissa represents the jet pressure in atmospheres. These are given non-dimensionally so that the same curve applies to the model and full-scale article. The dimensional data corresponding to the test ranges are also given in Table 1. All air temperatures were essentially atmospheric throughout the test. The pressure necessary to dissipate the vortex with any orifice diameter located the corresponding test point on Fig. 5 and gave the data shown. It may be noted that less than 1/10 of 1 per cent of the engine air was found sufficient to dissipate the vortex at high pressures. This figure increased for the larger orifices associated with lower pressures.

During the course of the tests it was found that a scatter band existed in the quantity of air selected as that required to dissipate the vortex completely. This scatter, shown in Fig. 5, was due primarily to the fact that the vortex reappeared instantaneously from time to time at marginal pressures thus making it difficult to choose the exact pressure at which the vortex was completely banished. This momentary appearance of the vortex in no case picked up any material, however. The data shown include two separate tests with separate observers.

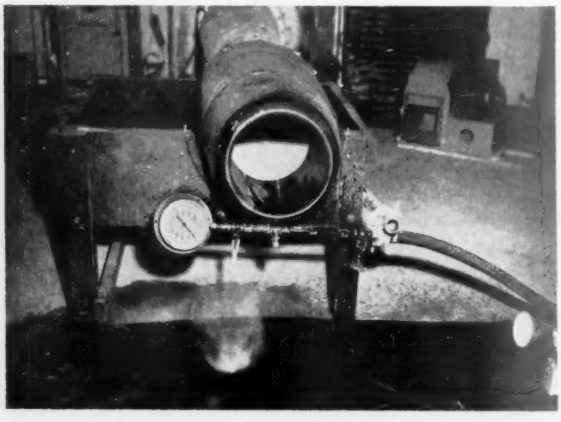


FIG. 4. The vortex formed in front of the inlet over a wet floor.

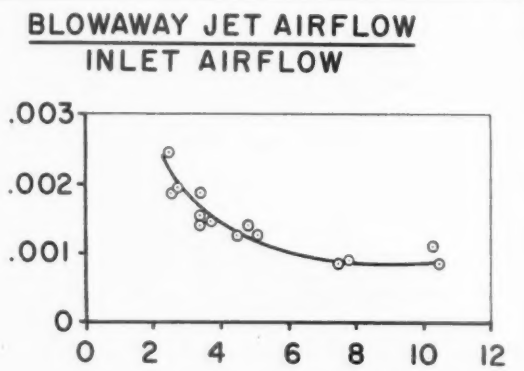


FIG. 5. Air requirements of blowaway jet. (NOTE: See Table 1 for operating conditions.)

If the air quantity was equal to or greater than that of Fig. 5, the blowaway jet proved to be perfectly consistent. When the jet was turned on to a sufficient pressure, the vortex disappeared in all cases and material was not aspirated. When the jet was turned off, the vortex reappeared and sucked up various materials.

The inlet height parameter Z_i/D_i has not been varied as yet although such tests are planned. It would be expected from the foregoing that a higher inlet would require a less powerful blowaway jet and vice versa. The approach vorticity parameter, $\omega_0 D_i/V_i$, was varied over a wide range by altering the circulation blowers' position and exhaust velocity. An extremely rough measurement of this quantity was made. It appeared to exercise no large effect on W_j/W_i over the range investigated. The vorticities used while taking the data of Fig. 5 were made as intense as possible with the available blowers.

The approach velocity was varied in an attempt to simulate head- and cross-wind effects. The winds simulated were of the order of 20 ft. per sec. These

simulated winds were achieved by means of auxiliary fans directed horizontally toward the inlet. The effect of this on the functioning of the blowaway jet was not noticeable.

Varying of the nozzle height showed that a jet closer to the ground (low Z_j/D_i) required less air. For the data of Fig. 5 the height was held such as to be practical for a flush installation in the nacelle skin of the DC-8.

The depression angle β was found to exercise a large influence on the air required. Over a range of β from 60 to 90 deg. there was little change in air requirements. When β was 45 deg., however, very large values of W_j/W_i were required. When β was substantially less than this, the vortex could not be dissipated at all. The test data of Fig. 5 were run at $\beta = 70$ deg. which was found to be about optimum.

The density ratio ρ_j/ρ_0 was held at essentially unity during these tests. Available information—e.g., reference 7—indicates that the effect of density ratio would be noticeable but not crucial. It was neglected here.

The materials which were sucked up by the inlet with the blowaway jet inactive consisted of pebbles as large as 3/4 of an inch in diameter, large aircraft-type rivets up to 1/4-in. shank and $1^1/_2$ in. long, various washers up to $1^1/_2$ in. in diameter, sheet metal strips up to 6 in. long and 0.020 in. thick, metal clips and other metallic parts. In order to explore whether materials free to roll could be sucked up, 1/2-in. marbles were distributed below the inlet, and it was found that these also could be sucked up readily by the inlet. Rags could also be sucked by the inlet, but usually they were sufficiently light to be blown away by the periphery of the vortex. It appeared that to be readily picked up, a material should be neither too heavy nor too light. The size of the foreign particles at full scale would be the same as at model scale—that is, the 3/4-in. pebbles picked up during model tests correspond to 3/4-in. pebbles full scale.

It should be mentioned that sucking up of anything by the inlet was a comparatively rare event. When a considerable amount of debris was deliberately scattered beneath the inlet, it often took 1 or 2 min. for something to go up. No shower of items proceeded into the inlet at any time. As shown in reference 8, a full-scale test would pick up about six times as many items per unit time as a model (for the same debris below the inlet). However, even full scale, one would not expect a shower of items to enter an inlet, but from time to time one could expect material to be aspirated, depending on weather conditions and other aircraft slipstreams creating vorticity and on runway cleanliness.

Information other than the foregoing data on the amount of air required for the blowaway jet was also accumulated. The jet did not affect the inlet because of the small air quantities involved. Even when the jet was moved very close to the inlet and directed either in or out of the main inlet, no effect was perceptible.

The use of a multiple series of jets under the inlet in place of the single jet was tried, and it was found in all cases that more air was required with multiple jets than with a single jet. A single slit extending one inlet diameter across the bottom of the inlet also required much more air than did a single round jet. Tests were run with a 10-in. diameter fan which showed that the fan slipstream behaved essentially like the jet. The vortex was dissipated at sufficiently large angles of depression but not dissipated with a horizontal fan. The fan power required was of the order of one tenth that required for the jet, which was to be expected since a low-speed, large mass jet has a larger momentum output per unit power. The unwieldiness of a fan installation would, however, preclude its use under an airplane.

The effect of ground condition was also investigated. A very rough rubber mat with a ribbed 1/2 in. (model scale) construction was substituted for the smooth plywood floor. There was no perceptible difference in the blowaway jet effectiveness.

Conclusions

The following conclusions may be drawn from the blowaway jet investigation:

(1) The blowaway jet represents a simple, safe, economical scheme for effecting a very large reduction in the amount of engine damage to be expected due to material pickup from the runways.

(2) The performance penalty is extremely small since the airflows required are small.

(3) The foregoing features make it worthwhile to consider the installation of the blowaway jet on other planned and presently operational aircraft.

(4) The principle used in the blowaway jet appears to be one fundamental method to dissipate a vortex. Other applications of this principle have been speculated upon. For example, vortices in emptying tanks or small tornadoes might conceivably be dissipated or deflected.

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Rear Adm. D. J. Welsh, USN

The operational requirement is discussed from conception to completion with special attention placed on the elements which directly form and affect it.

Around the Requirement in Thirty Minutes

THE TERM OPERATIONAL REQUIREMENT is used by the Navy to describe the military operational need for a weapon system. In the case of naval air weapon systems, the requirement calls out combat and flight characteristics and the combat mission climate in which the system will perform. It includes background information, comments on the system's compatibility with other systems, first availability dates, and the life span of the system in terms of service use.

The language of the operational requirement is quite general. It is supplemented by a more detailed footnote called the development characteristic. The development characteristic describes in greater technical authority and detail specific "numbers" and performance dimensions of the weapon system. This elaboration upon the requirement follows outline agreements on the technical solutions workable within the time period involved. For purposes of discussion here, the operational requirement and the development characteristic will be considered as one.

A part of the staff of the Chief of Naval Operations (CNO), the Air Warfare Division of the Office of the Deputy Chief of Naval Operations for Air has the responsibility for documenting the operational requirement. But there are many elements from many places that affect the requirement, help to shape it, and influence it.

I wish to enumerate these elements that directly affect the operational requirement, and then discuss them individually. First, we shall see that a main source of authoritative information about needed weapons is the people who will fight with them—the personnel of the fleet. Secondly, CNO has the responsibility both for overall formulation of tactics and strategy and for initial prosecution of programs for the design and development of weapon systems. A third element is the aircraft industry which often comes forward with new ideas and aircraft systems and which always is the best commentator on its own production capabilities. Another element is the possibilities envelope offered by technology and science. In the business of naval air weapons development, much reliance is placed upon the findings and opinions of the technological personnel in the Bureau of Aeronautics. Collaborating with them are the basic scientists of the Office of Naval Research (ONR), private laboratories, universities, and again, industry's reservoir of basic research knowledge. We cannot plan weapons upon which a part of the national security is dependent without an eye to what the enemy is doing; so intelligence becomes another element. And finally, an element which may be blessing or bind, depending upon which color of ink is used, money.

To elaborate upon these elements which are the major ones contributing to the making of an operational requirement, let us first consider the fleet.

It is easy amid the tons of paper work we do in the bureaus to lose sight, sometimes, of the realities of the operating situation. Our eyes sometimes get carboned up from all those carbon copies. Or we get accustomed to looking for little compromises.

They tell of a sea-going young naval officer who did a 3-year tour of administrative duty in one of the bureaus in Washington and then found himself in command of a destroyer escort in the North Atlantic. One morning he came to the bridge and decided to increase speed.

Rear Adm. Welsh is Assistant Chief for Plans and Programs with the Bureau of Aeronautics.

"Full speed ahead," he ordered the OD.

"There's an iceberg dead ahead, Sir," reported the OD.

"Full speed astern," was the next order.

"There's an iceberg dead astern, Sir," said the OD.

Without a second's hesitation, the new skipper from Washington ordered, "Full speed sideways!" He had been overtrained at compromising.

It is not that bad, really, but in the drafting of an operational requirement we want to feed in the realism and experience of the men of the forces afloat. The using command will have quite definite ideas as to a system's ability to work and live in its ultimate environment. Observations on ranges, refueling estimates, cycle time, maintainability, spare parts and logistics planning, as well as more objective thoughts on the weapon's worth to the fleet and to the nation, can be obtained from the fleet. Of special value are the opinions concerning the ability of a projected weapon system to be compatible with existing systems; this is especially true in antisubmarine warfare systems where a whole complex of systems operate as a team.

The benefit of this sort of sea-going and flying experience is secured through the rotation of fleet officers through the organizations within the Navy Department. In other words, officers with operating experience will be assigned to planning or developmental units working on the new systems. Another way is by normal communications with the fleet. Letters, memoranda, personal talks, even the bull sessions after conferences are all channels through which operating experience is ground into problems. The end result is a most desirable commentary about a new requirement from an authoritative source, and it ranges from detail to mission concepts. I recall the story about the late Admiral "Pete" Mitscher who once asked the Bureau to redesign a gasoline cap. The Bureau asked him in turn for specifications. He said he didn't have any specifications but that he wanted "a cap that can be installed on the darkest night by the dumbest mechanic without any possibility of error." A terse statement, but a clear one, and the sort of realism that we get from the fleet.

From CNO we get the broadest guidance for the requirement. Overall planning for future naval operations is documented in studies dealing with long-range plans and programs, including aims, objectives, strategic implications, expected operating climates, and, in fairly great detail, the make-up of future forces and fleets. The need for effectively meeting the widest range of military and political situations in consonance with national policy and commitments, and with greatest economy, is pointed out.

As I mentioned earlier, the aircraft industry is one of the chief elements in the making of the operational requirement. Industry also may be the initiator of the requirement. This is not to say that industry may know all there is to know about all elements involved, but it is to say that when industry comes forward with a new concept for an aircraft such as the VTOL airplane and shows that it will work, then the other elements in the requirements system will adapt and adjust to it. In other words, when the company has "sold" its new idea, the requirement can be written around it. Sometimes this means the changing of requirements for existing missions, and sometimes it means the establishment of an entirely new mission requirement.

In addition to the aircraft industry which contains scientific and engineering talent of its own, another element which goes into the shaping of the requirement is the one of technology.

Aeronautical science and engineering talent in the Bureau of Aeronautics has a responsibility for keeping abreast of the state-of-the-art. They are in a particularly good position to comment upon, or even generate, new requirements. On the one hand they study the results of basic research performed in such places as ONR, NACA, industrial laboratories, ARDC, the universities, and friendly foreign nations. On the other, they are involved with applied research for air weapon systems that are committed to, or already in, the hardware stages. It is their job within the Navy to show what is technologically feasible in naval air weapons design. It is their job to know, and to make known to the requirements planners, just how far the technological envelope will permit us to go in air weapons design. Their work is compartmentalized, of course, with experts in each of dozens of technical areas such as power plants, structures, avionics, and so on. These are the people who will agree or disagree with the technological feasibility of establishing a new requirement concept or will decide whether the contractors' claims relative to the state-of-the-art are reasonable. They draw us a road map, if you will, showing where technology will allow us to go, and from that we decide where we will go.

Military intelligence has always been an element in the drafting of an operational requirement. It is gratifying to see, at the present time, a quite vigorous application of foreign intelligence estimates and summaries. Operational analysis as performed both in CNO and in BuAer contains the strong factor of what is known about Soviet capabilities and intent, the location and concentration of military materials, and the expected defenses to any sort of penetration. The need for these considerations is obvious. If we have knowledge of the type of defenses surrounding the objective of a stated naval air mission, then it would be foolish indeed not to feed that information into our plans for building a weapon to perform the mission.

The final major element that influences the stating of the operational requirement is the fiscal consideration. It would be nice for the technical and military planners if money and the administrative decisions involving money were not a factor. It would be nice indeed if the R&D and the procurement administrators had blank checks. But they do not. It is apparent then, that some new ideas and applications would cost more than the Navy can afford. Others may have a reasonable price tag but are of such magnitude that funding for existing requirements and weapons systems may have

to be adjusted. It is imperative that the requirements planners and writers keep the fiscal and overall administrative policy makers briefed. This they do on a continuing basis up through the Secretary of the Navy and Secretary of Defense levels and at the earliest possible time when new systems are emerging. If the administrative and fiscal executives are not cut in on a new system or requirement until the last minute, adequate attention to the merits of the weapon requirement and consent for prosecution may not be secured. The result is insufficient fiscal support and subsequent delays which lead to the old story of "too little, too late."

I have mentioned some of the stronger elements that come together to form the operational requirement: the ideas of the fleet, the aircraft industry, the staff of the Chief of Naval Operations, technology and the aeronautical sciences, intelligence, and John Dollar.

Well, which comes first, the chicken or the egg? Which element takes the lead? Which is the most important? And where does actual initiation of a new development begin?

I will be among the first to call for patience in trying to provide answers to these questions. I will also be among the first to say that sometimes it tries the patience.

In the live situation, the basic idea which stimulates action to the point of writing a new requirement may emanate from any of the elements. From there on it is a matter of getting the comments and ideas of authoritative sources in the other elements. If interest is sufficient, the project gathers momentum through talks, conferences, presentations, and correspondence. When a reasonably clear meeting of minds has occurred, then the requirements writers will put the project on paper in the requirements language.

The most frequent sources for new requirements are the aircraft industry and the technological family.

When industry has an entirely new idea, or when it has a scheme for better accomplishment of an existing mission, representatives of the parent company will make presentations to the armed forces. They will show as much or as little detail as is necessary to explain their system. They will take the presentation to many offices and staff echelons within the interested agency. They will try to reach as many people as possible who have anything to do with the approval or the writing of the requirement. It is not unusual for a company to make eight or ten presentations to different groups within the Navy. And the company does not necessarily know with whom or where the spark will be ignited that will start initiation of the requirement and will lead to developmental and procurement action. This fact, I think, illustrates the team play among the elements which shape the requirement.

We in the Navy think this is a healthy situation. It means that a proposed new air weapon system literally has to sell itself on its own merits. The new proposal has to be attractive enough to some one of the Navy experts, such as an operational planner, or a scientist, or engineer, so that he, in turn, begins to convince others through talks and correspondence.

A hypothetical example of a requirement originating among the technologies, or from BuAer, might be where the state-of-the-art of seaplane design shows a proved promise of high performance. To get a little wild in my example here, let us say that wind tunnel, tow tank, and engine data show that a Mach 3 attack seaplane is possible. Let us say that BuAer sponsors this project. Again, through presentations, talks, and correspondence with authoritative people among the other elements, the project may gather momentum to the point where it is "bought" as an operational requirement.

The air rescue helicopter is a good illustration of where the fleet lays down the requirement. Carrier and task force operations require flights from decks around the clock and occasionally result in a ditched aircraft. To save the precious pilot and crew, the rescue means must be immediately available and fully competent to carry out the mission over the open sea in all conditions of weather and visibility. The requirement, in this instance, has to be thought of in terms of the physical details of the mission, and these details are known best by the men of the fleet.

Regardless of the point of origin, the final writing of the requirement must be tempered with the experience and the detailed knowledge of all the other elements involved. We cannot build a system even though it may be the most desirable if we do not have the money to pay for it. We should not plan systems which industry says we may have in the year 1962 if intelligence indicates that that system in that year will be hopelessly out-classed by the enemy. It would be nice to have a guided-missile base on the moon, but technology must be listened to when it says "not yet."

Under the Deputy Chief of Naval Operations (Air), the Air Warfare Division (OP-55) is responsible for writing the operational requirement and the development characteristics for manned aircraft weapon systems. About 18 of the 35 officers assigned to this division write and review the operational requirements for naval aircraft weapon systems. They are divided into groups according to mission areas such as attack systems, antisubmarine warfare systems, air-borne early warning systems, and so on. As we mentioned before, these officers are rotated from operating commands, and they are knowledgeable from the standpoint of fleet experience within their mission areas. The tables of organization and functional statements for these groups require that they:

(1) Maintain liaison with the Strategic Plans Division of CNO and the Division of Naval Intelligence.

(2) Formulate, in accordance with approved objectives and intelligence, the long-range and the short-range measures necessary for the coordinated development of the most effective aircraft and equipment.

(3) Maintain liaison and coordinate for naval aviation the technical and tactical development of

such offensive and defensive measures as may be required by developments in all types of air warfare.

(4) Keep informed of the qualitative readiness of naval air combat units.

These are the people who will take the results of all the interplay among the elements influencing the requirement and, upon a joint decision by CNO and BuAer, write the descriptive matter into the requirement which will call out the weapon system. They communicate in detail with any and all who are interested in the specific type of weapon.

The main avenue of traffic for the requirement writers runs between them and the BuAer which has the end responsibility for meeting the requirement in terms of procuring the hardware. As we implied earlier, a new requirement may begin at either end of the street. Let us suppose that an aircraft manufacturer comes to BuAer with a new concept for a high-altitude fighter. He makes a presentation to the Bureau Research and Analysis Officer whose staff have duties in aerodynamics research, structures, performance analysis, and evaluation. If the response is favorable, the contractor may be asked to give his presentation to the Assistant Chief of the Bureau for Research and Development. He may be asked to give it again to component divisions of BuAer such as Power Plants and Avionics. By this time the project is being talked about and written about, and a presentation is arranged for CNO or the requirements writers. Intelligence and budget factors are fed in.

There then begins a period of analysis and discussion about the new proposal that perhaps gets to be a time problem in the same way lead time in production is a time problem. This period of analysis and discussion may last 6 months, or it may last as long as 4 years. It depends upon how long it takes for the need for the new weapon to define itself and to crystallize.

We are trying to cut down on this time in several ways. One is by paying more attention to the policing of plans and programs. This involves my job as Assistant Chief of the Bureau of Aeronautics for Plans and Programs. My staff will monitor the traffic between the technical experts in the Bureau and the requirements planners in CNO. Inventories of new proposals will be set up, together with reasonable time schedules and progress feedbacks. Under the recently introduced concept of program managers in BuAer, my group is responsible for: assisting CNO in evolving operational requirements, disseminating operational requirements to cognizant BuAer divisions, monitoring performance on active operational requirements, and reviewing existing operational requirements to determine if modification or deletion is indicated.

Another timesaver is the BuAer Long Range Research and Development Plan. This plan shows in general what the anticipated weapon systems will look like for the next 10 years. It is based on the best estimates that can be made about what will be technologically feasible in the future, or what extrapolated states of arts will allow. The plan in many instances should cut down the time given to discussion and analysis simply because the analysis may have already been done.

To get back to the contractor and his proposal for a new fighter plane, let us say that a year has lapsed in the analysis and discussion phase. All elements are agreed, and the need is established. The requirement is drafted and circulated to all interested people. Final comments are then used to modify the requirement, and it is issued officially. The official approval is made by the Research and Development Review Board which is composed principally of interested Deputy Chiefs of Naval Operations, and the Chief of Naval Research. At the present time, there are some 74 active operational requirements for naval air weapon systems.

I do not consider a discussion of the operational requirements of the Navy complete without some mention of the problems involved. It is easy to show what happens and where and give the impression that things tick along with no strain. We mentioned the time factor in the period where the proposal for a new air weapon is discussed and analyzed before it is formed into a written requirement. There are other problems and shortcomings.

One of the things that urgently needs more consideration in the beginning, or in the requirements writing stages, is the maintainability of the weapon system. This, of course, is tied into the need for simplicity of systems. Today's high-performance airplanes almost need a test pilot or quasi-scientist to operate them efficiently and to save them once the pilot gets into trouble. This complexity of the machine also presents maintenance difficulties for the men of the fleet who have to keep them "up." Some advances have been made, but it is my feeling that much more can be done toward ease of maintenance and repair if detailed thought is directed to that area at the time the requirement and the development characteristic are called out. The same goes for logistics and spare parts provisioning and for component equipment reliability.

We need new ideas. We all realize that many technical problems remain to be solved in high-speed flight, in engine design, in underwater sound, and in many other areas of special interest to naval aviation. The technological breakthrough is "money in the bank," and our requirements system should stimulate both industry and service personnel to perhaps more original thinking than it does at the present time.

This, I realize, has been somewhat a tour de force around the Navy operational requirement. In closing, I should like to leave these thoughts about the requirement with you.

The Navy operational requirement once it is approved, published, and disseminated amounts to a charter authorizing the material bureau (BuAer) to proceed with contractual development leading to the quantity procurement of the weapon system.

The requirement is the key to industrial participation in the naval aviation program. The manufacturer can both generate requirements and participate in the

(*Continued on page 68*)

The SeaMaster is discussed in terms of its design problems and the accomplishments of its first flight tests. Also included is a report on the accidents as well as a summary of what was learned from them.

The SEAMASTER

Its Development and Some Considerations From the Accidents

J. L. Decker
The Martin Company

MORE THAN THE USUAL AMOUNT of interest which accompanies a new aircraft has been evidenced in the Martin XP6M-1 SeaMaster. As the world's first multijet seaplane, it represents the keystone of a new operational concept of naval warfare. Both prototype aircraft have been lost in flight test, and because of the importance of the airplane in the defense picture, a review of the aircraft and the accidents is considered to be timely. Security restrictions, of course, will prevent discussion of certain aspects of the aircraft and its design.

The advent of the jet engine has been the key to the development of the high-speed seaplane, even more than is the case with landplanes. Since it is essential to keep propellers out of heavy spray, propeller-driven seaplanes were saddled with very large frontal areas to maintain the required spray clearance. This resulted, inevitably, in a high drag configuration. A glance at the XP6M-1 (Fig. 1) indicates that a low, compact profile may be obtained with a jet seaplane, with good drag characteristics as a consequence. Futhermore, the wing cathedral employed for improved dynamic lateral stability enables the wing floats to be mounted at the wing tips without recourse to high drag float struts.

Recent hydrodynamic developments such as the long afterbody hull, low chine bow, and greatly reduced step depth have all combined to permit the design of a hull which has a drag coefficient quite competitive with the best fuselage forms. The seaplane, therefore, can be developed to performance levels comparable in every respect with the landplane.

The XP6M-1 was designed to an operational requirement issued by the Bureau of Aeronautics in April, 1951, and the design work was initiated under contract in October, 1952.

The author is Chief Aerodynamics Development Engineer.

FIG. 1. The Navy's XP6M-1 Martin SeaMaster, world's first multijet seaplane.

THE DESIGN PROBLEM

The two prototype XP6M-1 aircraft were powered by four Allison J-71 engines with take-off afterburners. The next six YP6M-1 "evaluation" aircraft, the first of which is due to fly within a few months, will be powered by the same engines. Production SeaMasters, however, will be powered by four Pratt & Whitney J-75 turbojet engines. The plane has a take-off gross weight in excess of 160,000 lbs. and is designed to carry a 30,000-lb. pay load at high subsonic speeds at low altitude. Its speed is over 600 m.p.h. and the mission radius over 1,500 miles. The design implications of the required mission are far reaching and unique to a large aircraft. The required values of flight dynamic pressure are several times the design values for other contemporary heavy aircraft. The consequences of the high dynamic pressure values are that the aeroelastic properties of the aircraft are of first-order importance.

For example, the loss in longitudinal stability due to aeroelastic deformations of the wing, hull, and tail at the sea-level design speed approximates the entire normal center-of-gravity travel of this type of aircraft. Control surfaces, such as conventional elevators and ailerons, may become almost totally ineffective at these speeds. Consequently, an all-movable horizontal tail and spoiler

ailerons have been employed for longitudinal and lateral control.

A better appreciation of the aeroelastic problem of the XP6M-1 may be achieved by considering that the design dynamic pressure on this aircraft approximates that of current jet fighter aircraft, although the design load factor is about half that for a fighter design. Consequently, the strength which must be built into the aircraft is relatively less than is the case for fighter designs. As a corollary effect, the rigidity of the XP6M-1, or any aircraft with a moderate load factor requirement, is relatively less than the rigidity of fighter aircraft.

The requirements of store dropping at high dynamic pressure are also a real challenge to the aircraft designer. The SeaMaster employs the Martin-developed rotary bomb door in the hull bottom. It is evident that the incorporation of a movable door in the hull bottom poses a formidable sealing problem, which, happily, has been successfully solved.

The performance of the XP6M-1 proved to be such that a first-line jet-fighter aircraft is required to provide adequate chase plane coverage for flight testing. Fundamental design characteristics such as wing sweepback, thickness ratio, and camber were determined from consideration of the problems associated with transonic flight (trim and stability changes due to compressibility, wing drop, buffeting, etc.). Because of the large aircraft size, the dynamic pressure, and the Mach effects on hinge moments, all control surfaces are power operated.

Some Design Considerations

The SeaMaster incorporates the T-tail arrangement which has almost become a Martin trademark since it was first introduced on the experimental USAF XB-51 jet bomber. The T-tail is not a panacea for all empennage design problems, but it does have some attractive features, as well as some which are not attractive. It very effectively raises the horizontal tail above the heavy spray, and this is a significant attraction to the designer of a seaplane. Furthermore, it produces directional stability very effectively, and horizontal tail dihedral may be used to advantage in this regard to utilize the favorable interference effect between the horizontal and vertical tails in sideslipping flight.

However, some difficulties have been experienced with T-tail aircraft in maintaining adequate longitudinal stability near the stall. In the case of the XP6M-1, the design philosophy was based upon the use of stall control devices on the wing to obtain a stable model minus tail pitching moment near the stall. Through the use of wing leading-edge slats, this end was achieved essentially, although a slight unstable tendency preceded the stable break at the stall.

Wind-tunnel results showed the complete-model and model-minus-tail pitching moments at the stall to be very similar. The cambered and twisted wing also evidences very little tendency toward the development of asymmetric rolling moments near the stall. In general, we expected acceptable stalling characteristics as a result of our tunnel tests.

The wing optimization studies showed that a wing aspect ratio of 7.0 would be optimum from the standpoint of performance—that is, a minimum weight aircraft to meet the mission requirements would result with aspect ratio 7.0. However, we did not build the aircraft with this wing for two reasons:

(1) The pitch-up problem at the stall with an aspect ratio this high would be extremely difficult to cure in a seaplane.

(2) The aeroelastic effects upon longitudinal stability would be excessively large.

The aircraft was designed with a wing aspect ratio of 5.25 in deference to the above problems, at a range penalty of only 3 per cent from the optimum.

The hydrodynamic design of the XP6M-1 is featured by the hydroflap installation. These surfaces are located in the hull bottom near the stern post and, deflected singly, serve as water rudders. Deflected in unison, they operate as water brakes. The use of the long afterbody hull makes it quite important to provide directional control at low speeds in the water since the hydrodynamic directional stability of the hull is quite high. Incidentally, the hydroflaps also double in brass as dive brakes. In this function, they cause very little trim change, which, of course, is a very desirable characteristic.

Flight-Test Accomplishments

In this article, it is not possible to present the results of the flight-test work in anything like complete form because of security considerations. However, in over 100 hours of test work, sufficient data have been obtained to establish the aircraft as possessing exceptionally fine flight characteristics. For example: The Mach range has been rather completely explored with an absence of critical compressibility problems. The XP6M-1 pilots report that little pitching or rolling tendencies have been evidenced in the aircraft's stall maneuvers, although unstable pitching moments at the stall are present in many current high-speed aircraft. And while the aircraft has been flown extensively to explore high-speed "tuck under" conditions, only mild tuck forces have been experienced in the longitudinal control.

The spoiler control on the XP6M-1 has proved particularly effective with the flaps down. This effectiveness actually had to be reduced in order to prevent an oversensitive control for take-off and landing operations. It was accomplished by lagging the motion of one of the two spoiler segments for small wheel motions from the neutral position.

Although a yaw damper is planned for the P6M production airplane, all flights thus far have been made without the damper, and the "dutch roll" damping has been adequate for the flight conditions investigated.

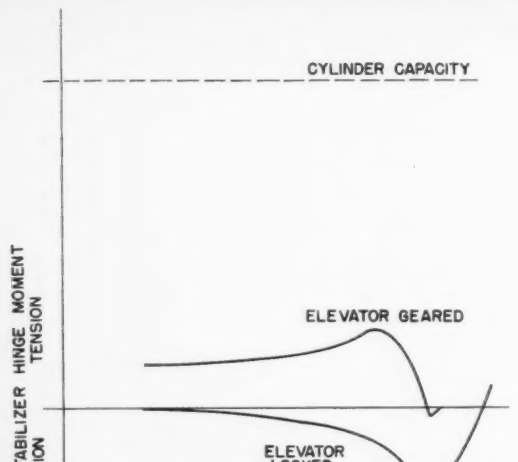

FIG. 2. Graphic display of XP6M-1 hinge moment characteristics.

The damper is deemed essential, however, for extended cruise operation at high altitudes.

A number of store drops have been made with the rotary door, and the store delivery system has functioned satisfactorily. The door opening sequence is not accompanied by undue aircraft roughness at high speed. Store separation has been positive and smooth with little tendency toward store gyrations. The high-speed drops have been recorded by cameras located in the wing tip floats.

The primary flight problem associated with the XP-6M-1 aircraft was the presence of an aircraft vibration over some speed ranges. The manifestation of this in the first aircraft was quite mild and undue attention was not given to the problem. With the second aircraft, however, the vibration characteristic was somewhat more aggravated, and a substantial amount of flight time was devoted toward the solution of this problem. As those engaged in the industry well know, the isolation and cure of inflight vibrations is a painstaking cut-and-try process. On nearly every flight of Ship 2, some aircraft modification or tufting was done in an attempt to effect a solution to the vibration problem. The modification made on the last flight only—namely, the locking of the geared elevators in a fixed neutral position—substantially reduced the inflight vibration.

THE ACCIDENTS

The first test ship, which made its initial flight in July, 1955, crashed in December, 1955. The four-man crew was lost and since the ship went down in the mouth of the Potomac River, reconstruction of the accident sequence and determination of the accident cause was an extremely difficult process. Through the painstaking efforts of U.S. Navy salvage teams, approximately 85 per cent of the aircraft was recovered from water depths ranging from 50–70 ft. and made available for analysis. It was established conclusively that the wings failed in negative bending. There were no indications of anything but a pure pitching maneuver prior to aircraft failure. The accident was attributed entirely to a controls system malfunction, among which were the following possible initiating causes: a minor explosion in the center wing stub which may have damaged control cables, hydraulic lines, or electrical circuits; a broken or snagged control cable; loss of pilot feel-force in the longitudinal control system; elimination of hydraulic power from the stabilizer actuator; pilot error in handling the controls.

Ship 2, which first flew in May, 1956, was lost on its twenty-fourth flight in November, 1956, near Odessa, Delaware. All four crew members escaped safely by the use of their ejection seats. Complete telemetered data and chase plane coverage were obtained and it was possible to establish clearly both the accident sequence and its cause.

As mentioned earlier, the longitudinal control system had been specially modified on the last flight to investigate the vibration problem. The elevator, which is normally geared to lead the stabilizer motion for improved low-speed control effectiveness, was locked to the stabilizer in a fixed neutral position. But with this modification, the stabilizer hinge moments (see Fig. 2) for the tail surfaces became unexpectedly large at the high test speeds, and the stabilizer actuator was overpowered. The leading edge of the stabilizer was driven down by the overpowering moments, producing a nose-up aircraft pitching moment. As the aircraft responded to the stabilizer motion, increased stabilizer leading-edge down-hinge moments were developed which resulted in further increases in aircraft angle of attack. The normal load factor increased to 9.5g's before the ship slowed down sufficiently to permit the stabilizer actuator to govern the stabilizer position again, and the stabilizer returned to its trim position. Angles of attack in excess of 60° were achieved in the maneuver and the hull drag force was responsible for approximately 1/3 of the normal acceleration. In this violent maneuver, the aircraft remained essentially intact. Only such items as the wing slats, outboard spoilers, and hatches left the ship at this time. The overpowering maneuver occurred near 22,000 ft. altitude, and the aircraft ultimately broke up after falling to near the 6,000-ft. level.

Within the limits imposed by security restrictions, I would like to discuss some of the detailed technical considerations involved in the overpowering sequence.

In the design of the hydraulic system, the hinge moment output of the system was designed to be compatible with the stabilizer hinge moments produced by the all movable stabilizer-geared elevator combination, which is the standard XP6M-1 longitudinal control arrangement. Therefore, the compression hinge moment capacity of the cylinder is only a fraction of the tension capacity. When the elevator was locked in neutral, the

hinge moment required to trim the aircraft in level flight shifted substantially toward compression load as shown in Fig. 2. At a Mach Number approximating the high speed of the aircraft, there is another substantial shift in the stabilizer hinge moments in the compression direction. At a given speed and altitude, the level flight trim hinge moment will reach the capacity of the hydraulic system, although this flight condition, that of the accident, had previously been exceeded with the geared elevator configuration.

Once the capacity of the hydraulic system has been reached, the empennage behaves essentially as a free-floating surface in response to hinge moments which are in an increasing compression direction. Once this incipient cylinder stall has been attained, another very significant situation exists. When the stabilizer hinge line is ahead of the horizontal tail aerodynamic center—i.e., when the tail will trail with the wind in a stable sense—the horizontal tail ceases to supply an increment in aircraft longitudinal stability with increasing angle of attack. This is true since the tail will float at constant lift, under the condition of constant aircraft speed which is appropriate to short period maneuvers. Therefore, the aircraft is flying, to all intents and purposes, with the model minus tail longitudinal stability. In the last flight of Ship 2, the center of gravity was located near the aft limit and the aircraft became quite unstable in pitch, once the actuator was stalled. This, then, was the source of the rapid divergence to 9.5g load factor.

I would like to point out that the accident sequence was closely duplicated in our analog computer in our postaccident investigation.

Good design practice for other reasons dictates that the stabilizer center of pressure of the load due to changes in angle of attack should be aft of the hinge line as was the case with our XP6M-1 design.

Lessons From the Crashes

The loss of an aircraft, particularly an experimental ship, generates extensive study to ferret the cause and to take steps to prevent recurrence of the accident. It is essential that important lessons be learned from accidents and their subsequent investigations because an exceedingly high price has been paid. Just as the loss of another test aircraft in recent years emphasized the need for the industry to make certain dynamic stability analyses which are now routine, so there are principles to be learned from the XP6M-1 accidents. Only a few main points which are believed to be of general interest, however, will be considered in this paper.

Since the longitudinal control system was involved in the considerations following both accidents, it is fitting to describe it so the succeeding discussions may be better appreciated. Reference should be made to Fig. 3.

As indicated previously, the all-movable horizontal tail is power-operated. The control cables, pumps, valves, hydraulic lines and cylinders are duplicated to provide the required reliability. Since no hinge moment feedback exists, the pilot feel must be supplied synthetically. This is done by twisting a torque spring as a function of stick and stabilizer motion. The rate of the spring is varied with dynamic pressure and the anchor point of the spring is moved by an electric screw jack to provide trim. A small bobweight is included in the system to provide a stick force per g increment in all flight conditions.

Although the initiating cause of the first accident was never specifically established, an important technical lesson was learned in the postaccident investigation. In the design of the XP6M-1, a mock-up of the complete control system—mechanical, electrical, and hydraulic components—was employed in conjunction with an analog computer to simulate the airplane aerodynamics for studies of the overall system. A "pilot" could "fly" the mock-up from its cockpit by attempting to keep its nose on the horizon of a visual display. The mock-up was both an indispensable design tool and invaluable tool in the accident investigations.

Among the investigations conducted on this mock-up were the effects of feel system failure. With the pilot "flying" the mock-up, simulated feel system failures were made at the flight condition of the accident. In every case during these simulator tests, when either (1) a simulated gust was applied, or (2) the pilot initiated a maneuver (after feel system failure), an uncontrollable oscillatory divergence in pitch resulted. This divergence was aggravated by the pilot since the human being is an imperfect servo and has excessive phase lags due to his reaction time. The problem becomes particularly acute at high speeds, where the short-period aircraft pitching frequency becomes high. The control motions at high speed are very small and become relatively useless as a cue for the pilot to help him fly the aircraft. The pilot flies almost exclusively by force feel at the higher speeds. When these force cues are removed as by feel system failure, he is unable to fly the aircraft.

The results of this phase of the XP6M-1 accident investigation indicate, therefore, that the feel system

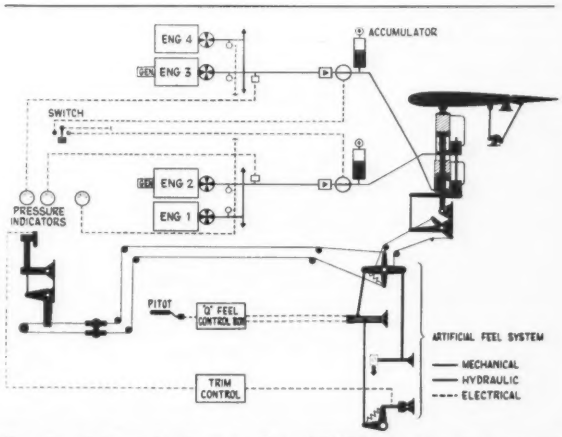

Fig. 3. Schematic diagram of the XP6M-1 longitudinal control system.

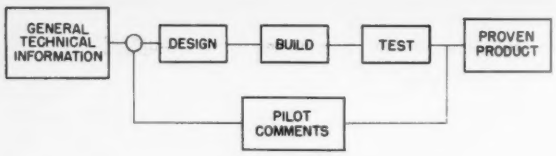

FIG. 4.

should be considered essential to the safety of flight and must be designed under the same failure philosophy as the power control system. It should also be mentioned here for completeness that the bobweight was effectively located at the pilot's column, where its adverse effect on the dynamic stability of the aircraft with a failed feel system would be minimized.

The major lesson to be learned from the Ship 2 accident is largely philosophical. In the cases where manual controls or proportional boost controls are employed, there is a direct feedback in surface hinge moments to the pilot. If the hinge moments are not what they should be, the pilot wastes no time telling the engineers about it so that corrective measures can be taken. The aircraft design is then based upon two sources of information, the general technical information available to the engineers prior to flight and "feedback loop" information from the pilot in the postflight conference. This is shown diagrammatically in Fig. 4.

With a power control system, however, the feedback loop from the pilot relative to surface hinge moments just is not there. He has no indication as to the hinge moment behavior, and if the feel system is well designed he is satisfied with the aircraft in this area. Critical conditions may build up without his knowledge. Therefore, extreme vigilance must be exercised by the engineers to ensure careful monitoring of the hinge moment picture to compensate for the removal of a traditional source of intelligence. Accurate instrumentation of the stabilizer hinge moments during flight test provides this required information in lieu of pilot information feedback.

The reliability of an aircraft has always improved with the passage of time because of the feedback of pilot opinion. As "gripes" appeared, corrective measures were taken. With missiles, the reliability history is sometimes reversed. As the highly trained manufacturer's test crews, who usually had participated in the design of the missile, were replaced by service operational crews, missile reliability has become worse in many cases. This reduction in missile reliability with time is, of course, partially attributable to the less favorable operational environment of service usage. But the prime factor, however, is the lack of information feedback relative to the flight from either test instrumentation or pilot comments. There is no pilot to correct in flight the single malfunction which could spell an unsuccessful mission, and then report the failure in order that future corrective action may be taken. This is another illustration of the importance of the pilot feedback information during the evaluation phase of the aircraft. Once the aircraft has demonstrated its flight envelope, however, the need for the feedback ceases to exist since the aircraft by then is a proven vehicle.

CONCLUSION

In an assessment of the SeaMaster program to date, the loss of both prototypes naturally stands out and tends to obscure the fact that over 100 hours of flight tests have indicated a successful solution to most, if not all, of the usual problems of high-speed flight. The one problem area of in-flight vibration, which was present on both prototypes to varying degrees, appears to have been cured by locking the geared elevators in a fixed position on the last flight of Ship 2. To provide for this aerodynamic improvement while at the same time providing corrective measures to prevent the possibility of overpowering the hydraulic system on future P6M aircraft, the tail assembly for the upcoming P6M models has been redesigned. The exterior configuration of the new tail, however, will largely resemble the configuration of the two XP6M-1 aircraft.

The postaccident investigations have also pointed out the essential safety-of-flight nature of the longitudinal feel system on power controlled aircraft. In addition, the great importance of telemetered flight-test information has been underscored, since it was telemetered information that made possible the rapid isolation of the cause of the second accident—namely, an overpowering of the stabilizer actuator by the stabilizer hinge moments under locked elevator conditions.

Finally, careful monitoring of the hinge moments during flight testing must be considered essential since no pilot feedback information is available with full power systems, a situation which is contrary to that of manually controlled aircraft.

NATIONAL NAVAL AVIATION MEETING PROCEEDINGS

The *Proceedings* of the Naval meeting (held in San Diego, Calif., August 5–10, 1957) will contain all *unclassified* papers presented at the meeting and will be available in November.

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LeRoy H. Clem
Air Weather Service, MATS, USAF

Clear-Air Turbulence Over the United States

In Project Cloud Trail, turbulence observations were collected and analyzed. The findings suggest that clear-air turbulence can be avoided to some extent.

Atmospheric turbulence of such intensity as to alter the smooth flight of aircraft has long been a familiar phenomenon to pilots flying at levels below 25,000 ft. Our present state of knowledge of this phenomenon does not permit us, however, to forecast its occurrence accurately. Fortunately, the vertical motion associated with turbulent airflow at these levels usually produces distinctive cloud formations which experienced pilots have learned to recognize. Pilots react to such cloud-warning signals as cumuliform and mountain-wave clouds by changing course to avoid them or by reducing flying speed so as to lessen the shock of the turbulence when the aircraft penetrates the cloud. This natural cloud-warning system, which has served us so well in lieu of a reliable forecasting technique, owes its success primarily to the fact that there is usually enough moisture present in these lower levels to allow the characteristic cloud systems to form.

With the coming of jet aircraft, it was expected that we would now be able to fly over most of the "weather." Unfortunately, this did not prove to be the case, for turbulence of sufficient intensity to affect aircraft is found to be common above 25,000 ft. At these high levels, however, the smaller scale of vertical motions and low moisture content do not favor the formation of cumuliform clouds. As a result, at the optimum altitudes for jet-aircraft operations, the turbulence frequently occurs "out of the blue," without benefit of a convenient warning by cumuliform clouds. Since the shock administered to an aircraft by a given degree of turbulence varies directly with the speed of the aircraft, it is obvious that this insidious clear-air turbulence is, and will continue to be, of primary concern to jet-flight planning. (Clear-air turbulence also occurs, of course, below 25,000 ft.; with respect to cloud turbulence, however, it is much more frequent in the upper levels.)

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Previous Research on Clear-Air Turbulence

Past studies on high-level clear-air turbulence present a confusing picture. British investigators made one of the earliest extensive studies of this problem. They found that heavy clear-air turbulence does exist at the higher levels but did not uncover any solutions to the problem of forecasting its occurrence. In this country some people felt, however, that the findings of the British were nonrepresentative and that their results were too pessimistic. Consequently, the problem was quietly put aside, in some people's minds, as being not particularly important. Soon, however, the "jarring" experiences of some of our own high-flying aircraft necessitated a re-examination of the problem. Various data-collection programs were initiated to fulfill design and operational requirements of jet aircraft. Several theoretical studies were prepared on the subject also.

Unfortunately, most of the high-level data-collection programs were restricted in some respects for various reasons and provided very few observations of heavy or severe turbulence. For example, the three-day high-altitude gust program (a joint effort of governmental services in the United States and Canada), was unfortunate in this respect because the desired synoptic situation did not develop during the alert period and the program had to be run under less desirable conditions. In addition, the plan called for turbulence observations at only two sampling levels (viz., 30,000 and 39,000 ft.), thus limiting the scope of the data. The results of this program did not show frequent indications of strong turbulence at the given levels. The U.S. Navy AROWA Project and the USAF Project Jet-Stream flights were hampered to some extent by navigational requirements which forced them in most cases to sample turbulence over the less-cloudy areas. In addition, the jet streams studied were usually restricted to southeastern United States, between 25°N and 35°N. This was especially true in the case of the USAF Project Jet-Stream in which extensive investigations of jet-stream details in the vertical cross section were made

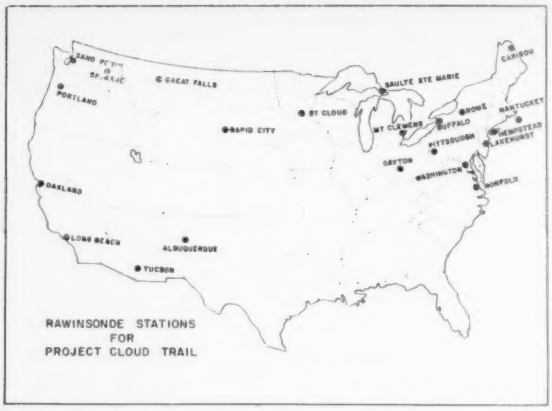

FIG. 1.

by flights involving several levels on the same track. Since such lower-latitude jet streams are usually weaker than ones farther to the north, over the northeastern United States, they are less apt to be associated with strong turbulence.

No attempt is made here to review the total work done on the high-level turbulence problem. The purpose of the discussion thus far has been to highlight the principal reason why another clear-air turbulence data-collection program was necessary—i.e., the need for a sampling of the three-dimensional distribution of high-level turbulence over the entire United States. This need was satisfied to an acceptable degree by Project Cloud Trail.

PROJECT CLOUD TRAIL

Project Cloud Trail was established within the USAF Air Defense Command in conjunction with the Air Weather Service to collect high-level weather information from jet aircraft. One purpose of the program was to accumulate sufficient data to serve as a basis for developing methods of forecasting turbulence at the levels of jet-aircraft operation. To obtain these data, the observational phase of the project ran for a one-year period from December, 1954 to December, 1955. During this period, pilots of fighter-interceptor aircraft collected high-level data in the vicinity of the upper-air sounding stations shown in Fig. 1. The pilots were careful to coordinate the time of each flight with the standard 1530Z upper-air sounding. They flew in a vectored climb from 25,000 ft. to maximum altitude of the aircraft, remaining, meanwhile, within a 30-mile radius of the rawinsonde station. During the climb, the pilot was requested to report whether or not turbulence was encountered, and if so, to subjectively evaluate its intensity. He was also requested to estimate the height of the base and top of each observed turbulence layer.

Mountain-Wave Turbulence

In the Project Cloud-Trail observations, no distinction was made between the turbulence associated with the mountain-wave phenomena and that associated with other synoptic features, although the stations were chosen so as to avoid mountain effects as much as possible. The turbulence associated with the mountain-wave conditions often extends to very high levels and can become very severe. The turbulence distribution associated with the typical mountain-wave pattern has been described by Jenkins and Kuettner.[1]

The Nature of High-Level Turbulence

The vertical motion associated with high-level turbulence appears to be more restricted in depth than is the large-scale up-and-down drafts of lower-level convective action. The aircraft flying in turbulence at high levels reacts in a manner similar to a fast speed boat as it pounds over rough, choppy water. Even in light turbulence, this characteristic presents a fatigue problem for both aircraft and occupants. The general areas of turbulence appear to be made up of patches which are rather shallow (500 to 2,000 ft. thick), narrow in width (10 to 40 miles), and elongated in the direction of the wind (they are frequently several times longer than wide). The occurrence ratio of turbulent patches to smooth patches within a given generally turbulent area varies from the order of 1:1 to about 1:10. In the vertical, the turbulence often occurs in multiple layers, which may have several thousand ft. of relatively smooth air separating them.

Limitations of Project Cloud Trail

For the purposes of turbulence investigation, the data obtained from Project Cloud Trail had definite limitations. In the first place, the pilot's evaluation of the turbulence was purely subjective, and the aircraft were all relatively stiff-winged fighter-interceptors. (At least the samples were homogeneous in this respect.) Secondly, it was possible for an aircraft operating under these conditions to climb through a turbulent area without encountering any turbulence, by penetrating a locally smooth patch within the generally larger area of turbulence. (The existence of such situations argues that perhaps turbulence forecasts should be worded in "probability terms.") Finally, because turbulence observation was not the primary purpose of these flights, there were times when poor weather at the terminal led to cancellation of the mission. Thus, as in the AROWA and USAF Jet-Stream Projects, the turbulence data obtained from Project Cloud Trail may well be biased (but to a lesser degree) toward better-weather situations. This bias could notably affect the indications on the frequency of intense turbulence, since poor weather at the surface (e.g., cyclogenesis) is frequently associated with the proximity of a jet-stream maximum-isotach center aloft. (One of the conclusions listed later in this report states that intense high-level turbulence is most often associated with such jet-stream activity.)

TABLE 1
High-Level Turbulence Reports
(Project Cloud Trail—1955)

	Missions Completed	Missions Reporting Turbulence	% of Missions Reporting Turbulence	Most Intense Turbulence Reported			Layer of Turbulence	
				Lt.	Mod.	Sev.	Single	Multiple
Dec.	292	131	45%	87	39	5	84	47
Jan.	325	113	35%	58	45	10	73	40
Feb.	274	80	29%	50	28	2	64	16
Mar.	309	73	24%	38	30	5	55	
Total	1,200	397	(Avg.) 33%	233 (19%)	142 (12%)	22 (2%)	276 (23%)	121 (10%)

Results of Project Cloud Trail

Previous studies have indicated that the more intense turbulence is most likely to occur during the winter months. In view of this fact, the first statistical compilation of Project Cloud-Trail results was made for the first four (winter) months of operation of this project (see Table 1). These statistics indicate that, on an average for the stations sampled, turbulence was encountered above 25,000 ft. on about 1/3 of the 1,200 missions flown from December, 1954, through March, 1955. However, this proportion varied greatly, both with time and space. Of the missions that reported high-level turbulence, about 1/3 encountered more than one layer of turbulence; three layers were not unusual. The more intense turbulence usually was found by those missions reporting multiple layers of turbulence; in such cases the individual layers were usually thicker. However, the observations of light turbulence outnumbered those of the more intense variety by about ten to one.*

Meteorological Aspects of Project Cloud-Trail Results

In order to associate the observed areas of turbulence with measurable meteorological parameters, the reports of each mission flown in the winter months were studied with regard to the corresponding distribution of wind and temperature in the vertical and along the standard constant-pressure surfaces. This study yielded certain qualitative indications that are worthy of note.

First, the occurrence of light turbulence, although more frequent than heavy turbulence, was not as clearly associated with specific synoptic features. Apparently, light turbulence can originate in various situations and can be propagated in space from the scene of its origin. Such propagation may be caused by turbulence "reflection" on interfaces such as the tropopause; the result is that the turbulence may be observed well after the stimulating force has disappeared. This condition also would be found, of course, in the final stages of strong turbulence which is dissipating. In view of these characteristics of light turbulence, no attempt was made to associate the synoptic features and turbulence of light intensity, rather, it seemed desirable to consider the somewhat clearer association between meteorological parameters and the more intense turbulence.

In the cases where flights reported moderate or severe turbulence, the high-level (300-mb. and/or 200-mb.) charts usually indicated a strong jet stream either over or somewhat to the south of the home station. In addition, a center of high-speed winds (isotach max) moving along the jet stream was in the vicinity of the station. An example of such a synoptic situation is shown in Fig. 2a. There appears to be a greater probability of occurrence of the intense turbulence below the jet isotach-max and on its north, or cyclonic, side. Given the general picture of this preferred synoptic situation, further details can be obtained from an examination of the upper-air soundings at various stations in the vicinity. As the maximum wind-speed center moves in, the increase in winds aloft can be noted on subsequent soundings. However, the possible inaccuracies of the current (as of January, 1957) upper-level wind soundings make it impossible to accept details of the wind profile (such as these vertical shears) with any confidence. Where temperature soundings are also available, the forecaster can make use of the fact that turbulence frequently occurs in or just below significant inversions like the tropopause.

From the Project Cloud-Trail example cited in the previous paragraph, vertical and horizontal cross sections have been constructed to illustrate the typical distribution of turbulence about a jet-stream max-isotach center (see Fig. 2b). The characteristic jet-core and tropopause configurations are also shown.

A few of the cases of intense turbulence reported in the Project Cloud-Trail data did not occur in conjunction with the above-mentioned jet-stream situation. Among such exceptions were situations involving the passage of sharp trough-lines aloft and deep upper-level cold lows.

Prior to the time that the potential shortcomings of the routine upper-wind profiles were realized, Project Rough Rider was initiated in an attempt to use details of the wind and temperature soundings in developing a forecast technique for high-level clear-air turbulence. While this project was in operation, indications again were found that there is a useful relationship between strong vertical wind shear, steep temperature lapse

* In tabulating turbulence occurrences for Table 1, only one report of turbulence was counted for each mission, regardless of the number of turbulent layers observed. The most intense layer was chosen as definitive for such a report.

rate, and the occurrence of high-level turbulence. Project Rough Rider was suspended, however, when information on the potential inaccuracies in the current routine windprofile data became available.

As a check on the association of pronounced turbulence with the three stated synoptic situations—i.e., proximity of jet stream, upper trough line, or upper cold low—the reports of all other missions flown in regions obviously not under the influence of these specific regimes were studied. Among these reports, there were few reports of strong turbulence except in those cases where orographic influence was a probable factor. It appears, then, that one fairly reliable way of eliminating the unexpected aspect of a pilot encountering pronounced clear-air turbulence at high levels

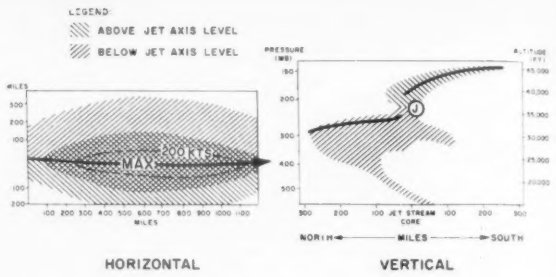

FIG. 2b. Vertical and horizontal cross sections of the typical distribution of turbulence about the jet-stream Max-Isotach Center of 1500Z, January 24, 1955.

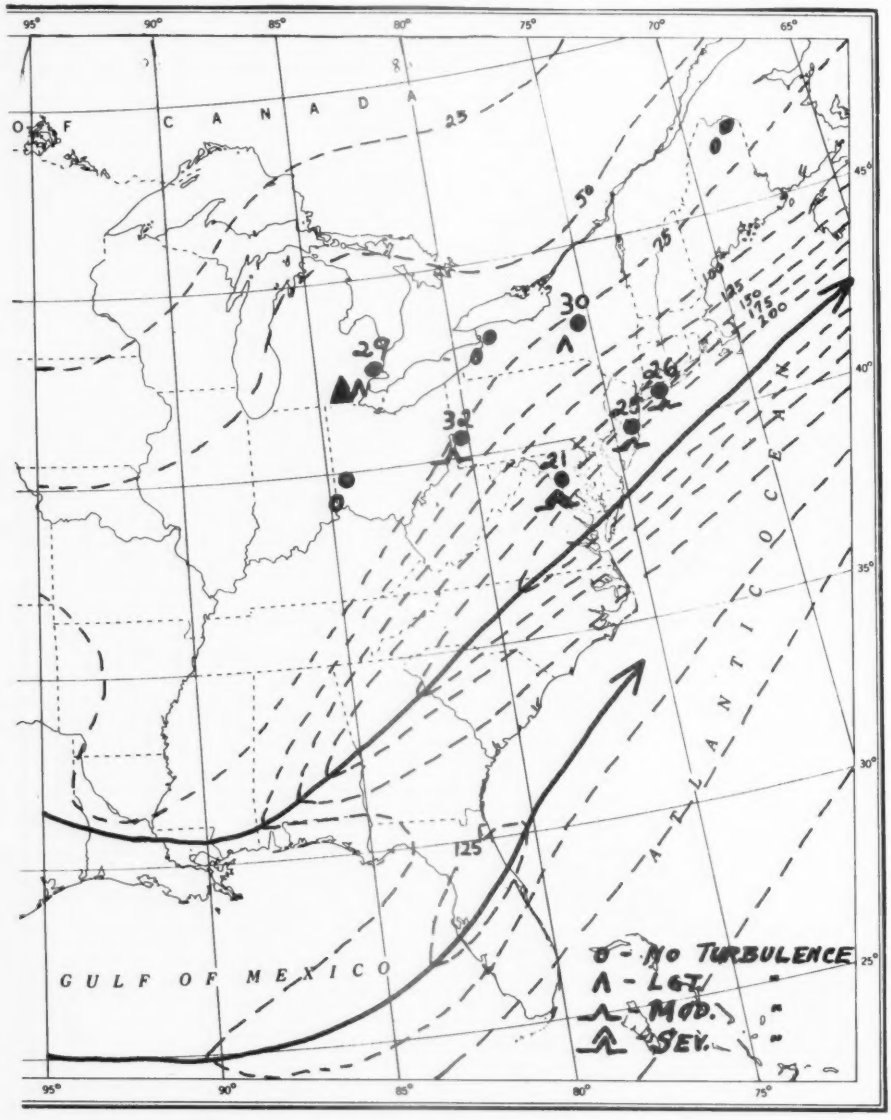

FIG. 2a. Distribution of observed turbulence in relation to the jet stream—1500Z, January 24, 1955. Dashed lines are isotachs (in knots) at 300 mb. Solid lines are the jet-stream axes. Number above the station circle is the altitude (thousands of ft.) of the most pronounced turbulence during climb of aircraft. Intensity of turbulence is indicated by appropriate symbols.

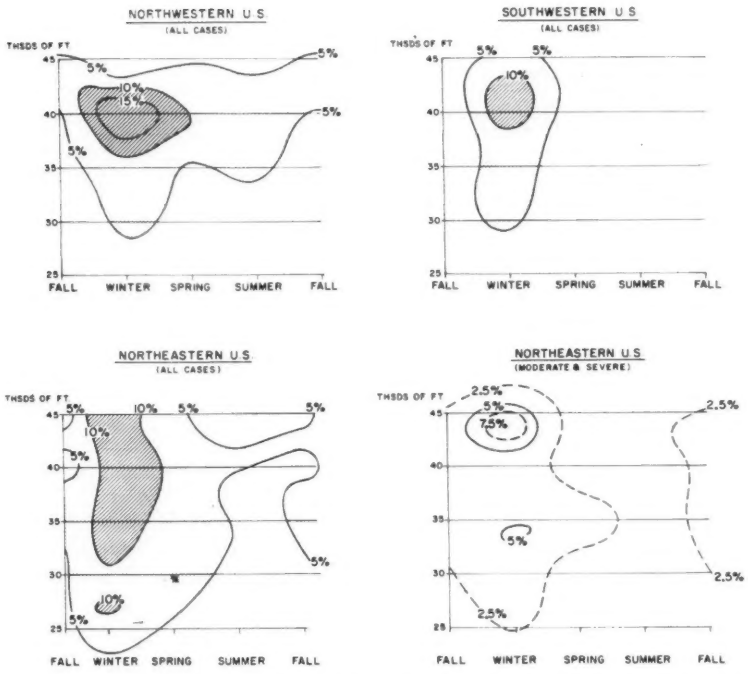

FIG. 3. Percentage of occurrence of turbulence between 25,000 and 45,000 ft. for each season (from data obtained at 1,000-ft. levels). Project Cloud Trail—1955.

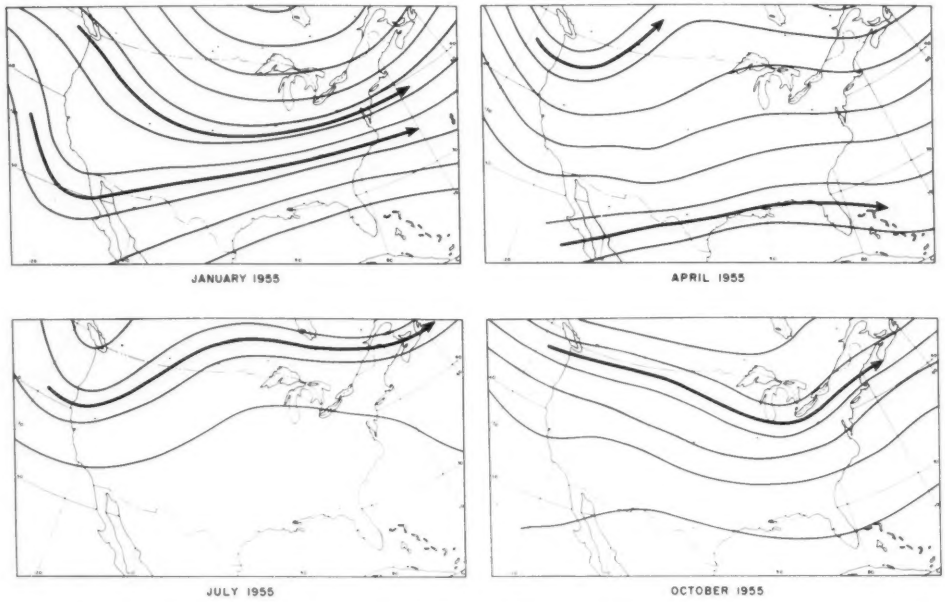

FIG. 4. Mean monthly 300-mb. contours and positions of the mean jet-stream axes for the midseasonal months.

would be to forecast its probable occurrence whenever one or more of the synoptic features listed above move into the area of concern.

Climatological Results of Project Cloud Trail

The Project Cloud-Trail data have been assembled in a climatological form in the hope of shedding more light on the confused picture of the frequency of occurrence of significant high-level turbulence. Since there is only one year of observational data available, it was necessary to group the observations from several stations together under one of three regional headings. The stations (see Fig. 1) were grouped as follows: those in the northwestern United States (these stations were probably influenced by mountain effects more than the other two regions), those in southwestern United States, and those in northeastern United States. The data from GRD's Project Jet Stream give information on high-level turbulence over the southeastern United States; the frequency and distribution of occurrence seem to be in general agreement with the findings of Project Cloud Trail, but the intensity of the turbulence was, on the average, lighter. The overall findings from Project Cloud Trail are shown in summarized (by seasons) form in Table 2.

The seasonal variation in the northwestern United States is rather small (28% in winter to 22% in the fall), while in the southwestern United States there is a variation from 33% occurrence in winter to 14% in summer. A pronounced seasonal variation is indicated for the northeastern United States, also. For the United States as a whole, the annual average of the percentages of flights during which turbulence was observed somewhere between 20,000 and 45,000 ft. was 24%. These results compare favorably with similar studies by the British[2] and Canadians.[3]

The Project Cloud-Trail data for the three geographical regions described above were further correlated to determine the percentage of occurrence of turbulence at the various 1,000-ft. levels from 25,000 to 45,000 ft. for each season. These values form the basis for the graphs shown in Fig. 3. The mean monthly 300-mb. contours and positions of the mean jet-stream axes for the midseasonal months are shown (see Fig. 4) as an aid in understanding the association of the percentage-of-occurrence groupings with the jet stream.

TABLE 2

Percentage of Time Turbulence Reported Anywhere During Ascent Between 20,000 and 45,000 Ft.

	Northwest U.S.	Southwest U.S.	Northeast U.S.
Winter	28%	33%	44%
Spring	24%	19%	32%
Summer	23%	14%	28%
Fall	22%	16%	27%

U.S. Annual Average: 24%

CONCLUSIONS

The data obtained during Project Cloud Trail indicate that high-level turbulence may be associated with recognizable synoptic features, and have systematic geographical and seasonal variations. These findings suggest that the insidious aspect of clear-air turbulence—i e., occurrence without warning—may be avoided to some extent by forecasting its probability of occurrence in association with certain synoptic situations.

REFERENCES

[1] Kuettner, J., and Jenkins, C. F., *Flight Aspect of the Mountain Wave*, Air Force Surveys in Geophysics No. 35, p. 9, April, 1953.

[2] Bannon, J. K., *Meteorological Aspects of Turbulence Affecting Aircraft at High Altitudes* (Meteorological Office, London), Professional Notes No. 104, Vol. VII, 1951.

[3] Lee, R., *Jet Streams*, The Roundel (published by Royal Canadian Air Force), pp. 16–21, July-August, 1956.

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Around the Requirement in Thirty Minutes *(Continued from page 57)*

meeting of the requirements he does not generate. From what we can tell of future contractor relationships, it appears that the manufacturer's participation will become even greater. He will be given more information about the military requirement and the accompanying operational analysis. As a step in this direction, the Power Plants Division of BuAer has presented its long-range plan to key personnel from all major engine companies. Other BuAer divisions are working on similar presentations. This implies a greater sharing of "BuAer secrets" and in proportion places a greater charge of responsibility upon the manufacturer. It is meant to encourage the manufacturer to embark upon basic research of his own to augment normal government and laboratory efforts to find the best solutions to problems in the many fields of technology connected with naval air weapons. Such an interchange of requirements information will demand of the Navy an orderly and conscious effort in good faith. From the contractor it will demand a single focal point for the authoritative exchange and evaluation of this sort of data.

Lastly, I want to emphasize the fact that the language of the requirement shapes the quality of future naval aviation and, in turn, naval aviation's contribution to national security. If the requirement is stated in terms that are half thought out, incomplete, or vague, a new proposal may suffer from halfhearted support and deadly delays no matter how good it is.

In conclusion, I should like to say: an outfit (military or civilian) is as good as its planning—and our plans are best expressed in requirements.

*"There is one segment of the aircraft industry's operations which, of course, is not affected by military reprograming. This is the commercial business. . . . There is a growing market in business and private flying, and new aircraft, designed especially for these markets, are coming along rapidly."**

Business Aircraft for the Future

Allan Bernhardt

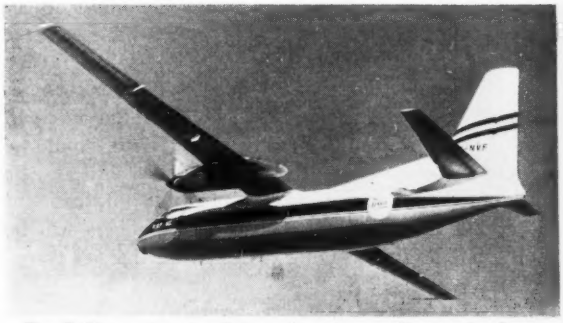
THE BUSINESS AIRCRAFT fleet in the United States is not destined only to swell in numbers through new discoveries of the convenience in corporate ownership of airplanes and increasing demands to telescope time. A look into the future by six United States aviation leaders at a recent IAS Panel Discussion† indicates that speeds of from 300 to 500 knots may be expected. In addition, multiengine business aircraft will fly higher, be more efficient and safer, and have greater utilization.

Panelists were Winfield Arata, Jr., Chief Operations Engineer, Fairchild Aircraft Division, Fairchild Engine and Airplane Corporation; John T. Calhoun, Design Engineer, Beech Aircraft Corporation; Ralph M. Harmon, Chief Engineer, Business Transport Aircraft, Cessna Aircraft Company; August Raspet, Head, Aerophysics Department, Mississippi State College; G. Edward Rice, NBAA Representative, Manager of Commercial JATO Sales, Aerojet-General Corporation; and Major Gen. J. W. Sessums, Jr., Vice-Commander, ARDC, USAF.

Discussing "Propjet and Turbojet Business Aircraft," Mr. Arata pointed out that, while they are not yet in wide use, planning by manufacturers, users, and Government agencies is going forward. His remarks excluded all but multiengine, high-speed aircraft.

Citing figures showing that 65 per cent of all civil aircraft are 10 or more years old, Mr. Arata outlined other studies made by Fairchild showing that there exists a market for a new business transport. A significant fact that came out of the 1955 Fairchild customer preference study was that one of the primary concerns of the business flyer is range. On this subject he observed:

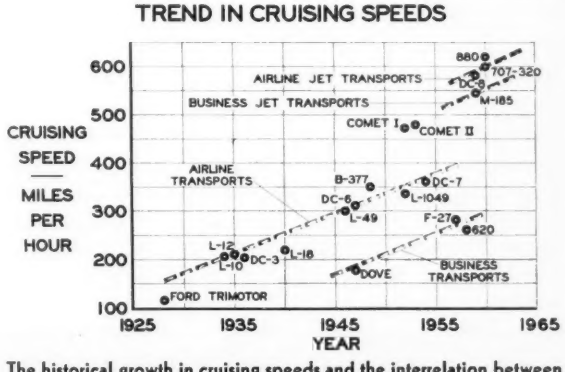
"It is understandable when some customers indicate that they would like to fly nonstop coast-to-coast.



The F-27 propjet aircraft is undergoing certification in Amsterdam, Netherlands, as well as being in production at Fairchild in Hagerstown, Md.

However, I am sure that all those people with this requirement realize that the airplane design is compromised for such range. Even with a moderate range, gas-turbine-powered aircraft can move across the country quickly; for instance, New York to Kansas City in 2 hours and 20 min. and Kansas City to Los Angeles in 2 hours and 50 min., even taking into consideration a 15 m.p.h. headwind."

Mr. Arata said he believed that the timing in the design and manufacture of aircraft has a great deal to do with its sales success, adding that Fairchild's F-27 propjet will be available to buyers in 1958 and that Fairchild's M-185 will make its appearance about 2



The historical growth in cruising speeds and the interrelation between the speed of business transports and air-line transports.

The author is Assistant Editor of the *Review*.

*** Quotation from Gen. Orval R. Cook, USAF (Ret.), President, Aircraft Industries Association of America, Inc., before the Aeronautics Committee, National Security Commission, the American Legion, Sept. 14, 1957, Atlantic City, N.J.**

† Symposium, IAS National Summer Meeting, June 17–20, 1957, Los Angeles, Calif. Chairman, William P. Lear; Senior Coordinator, Ben Cagle.

	300 Hrs. Per Yr.	600 Hrs. Per Yr.	900 Hrs. Per Yr.	1200 Hrs. Per Yr.
Fuel - 140 Gallons Per Hour @20¢ Per Gallon	$ 26.80	$ 26.80	$ 26.80	$ 26.80
Oil - .72 Qts. Per Hour @$2.33 Per Quart	1.66	1.66	1.66	1.66
Pilot- $12,000 Per Year Salary and Expenses	30.00	20.00	12.33	10.00
Depreciation - $250,000 Airplane Depreciation To 20 Percent Residual Value in 5 Years	100.00	66.67	44.44	33.33
Hangar Rent - $1000 Per Year Plus 50¢ Per Hour Away-from-Home Storage	3.00	2.17	1.61	1.33
Maintenance - .733 man-hours Per Flight Hour @$5.00	3.67	3.67	3.67	3.67
Reserve For Engine Overhaul - 300 Hour Overhaul Period and $3500 Per Engine Per Overhaul	23.33	23.33	23.33	23.33
Insurance -	10.52	7.01	4.67	3.51
Total Estimated Direct and Indirect Operating Costs Per Flight Hour	$206.50	$160.63	$129.03	$113.15
TOTAL Estimated Operating Costs Per Airplane Mile Based On A Block Speed Of 360 MPH	57.9¢	44.7¢	35.8¢	31.4¢

Estimated hourly operating costs for the Morane-Saulnier MS760 aircraft.

years later. These two aircraft, he said, "result from normal product development of a 300 m.p.h., 40-passenger local service transport and a 550 m.p.h. 8- to 9-place utility transport." He reported that executive owners are purchasing both types.

It is probable, Mr. Arata observed, that turbine-powered business transports will be in use for 10 to 15 years, and, as a result, direct operating costs should be reduced accordingly. His figures showed that the optimum direct operating cost per seat-mile can approach the cost per seat-mile that passengers will be paying on the forthcoming domestic air-line jet transports.

The expenses of business aircraft operation also occupied the attention of Mr. Calhoun, of Beech. "Equipment depreciation is the largest single item of expense in most business aircraft operations," he declared. "Therefore, provision of passenger carrying capacities larger than the average load carried on most trips represents an expense that is hard to justify. Airplane-mile cost, rather than seat-mile cost, becomes the most important factor in equipment selection whenever the load to be carried is less than the airplane capacity.

Mr. Calhoun said that surveys made by Beech showed that on most trips only three passengers are carried in the Beech Model 18 and that many trips are 600 miles or less in length. It was these two requirements—reasonable range and capacity for about three passengers—that were combined in design of the Morane-Saulnier MS760 airplane, Mr. Calhoun reported.

Most probably, a small jet aircraft such as the MS760 can be offered to the business fleet user at about $250,000, Mr. Cahloun said, adding that the price is "little, if any, more than the price of the engines alone for some of the larger jet business transports under consideration. The total price and consequently the depreciation charge for the small airplane will be approximately one-half to one-fourth the comparable charges for some of the larger proposed jet business airplanes. As shown in the accompanying table, the depreciation charge at a utilization of 900 hours a year accounts for about a third of the total airplane operating expense. In the case of larger jet aircraft, depreciation charges may well go above one-half of total operating expense. This is a serious penalty to be paid by the user who will need the increased capabilities only in rare instances."

Looking at some typical cases in which he said the increased speed of a small airplane can offer important advantages, Mr. Calhoun asserted that an ever-increasing percentage of business airplane trips are made to transport key trouble-shooting and technical personnel to cover emergency situations. "In most cases," he observed, "these people do not require the same level of comfort facilities demanded by top-level executives traveling in company airplanes. The seating arrangements and space offered by present-day small twins are adequate.

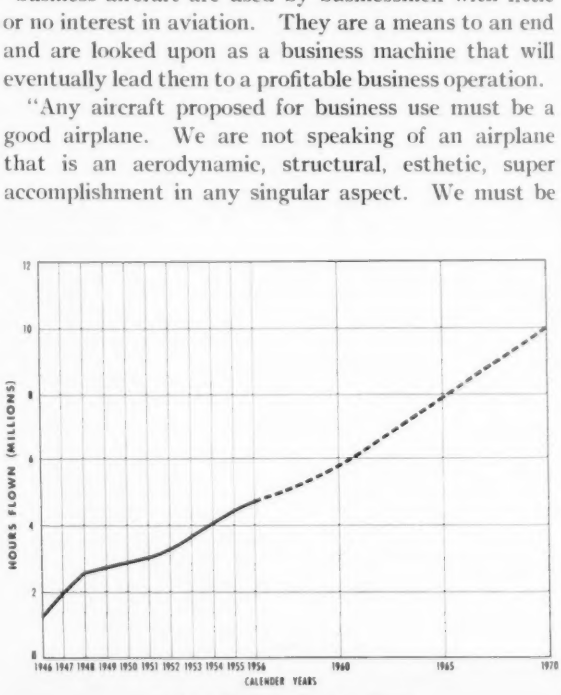
"On the other hand, minimum delay in getting these people to the site of the trouble is of prime importance. For this type of operation, significant time savings can be realized through the speed differential offered by small jets over present-day small airplanes even on relatively short trips. The MS760 offers block speeds of over 360 m.p.h. with 45 min. reserve at sea level on trips of up to 750 miles."

Mr. Calhoun described the role of the MS760 in the business fleet as one to provide significant time savings at a cost of 40 to 50 cents per airplane-mile. He added:

"Since depreciation costs of larger, longer range jet aircraft will be from two to four times those for the MS760, the airplane-mile costs for the larger jets will be much higher than for the MS760. Capacity for three passengers and 750 miles range with reserve covers a very large part of the load-range spectrum required by business airplane users."

On the subject "An Engineering Approach to Business Aircraft," Mr. Harmon, of Cessna, warned that "business aircraft are used by businessmen with little or no interest in aviation. They are a means to an end and are looked upon as a business machine that will eventually lead them to a profitable business operation.

"Any aircraft proposed for business use must be a good airplane. We are not speaking of an airplane that is an aerodynamic, structural, esthetic, super accomplishment in any singular aspect. We must be



Business flying forecast to 1970.

more fundamental in our definition. *A good airplane is one that is profitable to all concerned.* It is vitally important that this profit start with the manufacturer and continue through all phases of business aircraft, its manufacture and operation, because otherwise any nonprofitable portion of this aircraft's life will soon be the weak link that lets the whole operation start decaying. Our objective is to get a good airplane in every category that we choose to enter."

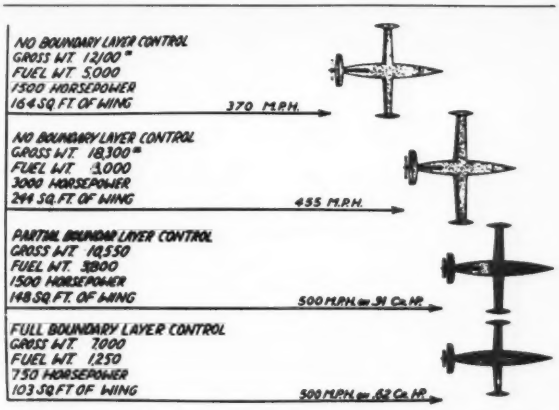
On the Cessna Model 620, a four-engine, pressurized aircraft designed for corporate use—and to invade the medium, heavy twin, and four-engine market—Mr. Harmon said the following factors were considered in an engineering approach to the aircraft:

> "The business aircraft industry is not subsidized. Development funds come only from profits. Safety and reliability are paramount. Customer is conservative. The unit and operating cost must be reasonable. Ability to service, support, and stand by product. Provide a service not presently offered. Is the financial gamble worth the effort? Is the aircraft appropriate for its intended job? What new engineering features can we use and stay within the above limitations?

"These considerations and limitations," Mr. Harmon declared, "will not produce radically different or unconventional aircraft for the business aircraft industry. We have often been criticized for not using the latest military developments and other generally known features in business aircraft. Aircraft employing unconventional features are supported by entirely different economic requirements, such as experienced in military aviation operation. The problems of pioneering advanced designs are accepted by the military customer, and the calculated risk involved is by his own specification. For many of them, business economic considerations are not a factor, since the only criterion is to provide maximum defense at any cost. At the engineering level, this fact is often difficult to understand during the design of business aircraft. Satisfying the business aircraft customer, that we are giving him the maximum that the state of the art permits, tests our intuitive know-how, also."

Taking up the "Contribution of New Concepts in Aerodynamics to Executive Aircraft," August Raspet said that "any aeronautical engineeer can easily visualize the utility that a business airplane would have if it possessed only a third of the drag coefficient, twice the maximum lift coefficient, and twice the static thrust of present-day business airplanes. "These," he declared, "are the contributions offered by the new concepts in aerodynamics.

"If we applied only a small degree of geometric boundary-layer control to our present-day business airplanes, we could improve their performance considerably. Some items that offer opportunities for drag reduction are radio antennas, cavities, such as unsealed landing gear openings, protuberances, leakage, sharp corners, deicer boots, coarse walkways, and other



Comparison of four corporation transport design proposals with pay load = 2,400 lbs., range = 2,700 statute miles, cruising W/S = 60 lbs./sq.ft.

roughnesses in the turbulent boundary layer. The detrimental effect that these items produce on an aircraft's performance does not seem to be too well appreciated by industry. A look at the turbulent skin-friction curve shows that the turbulent boundary layer, at a Reynolds Number of 10 million, doubles in skin friction for a roughness of 0.02 per cent of the chord. Quite obviously, even brazier-headed rivets exceed this roughness.

". . .Aerodynamic technology is at a state where better executive airplanes can be built with classical concepts, where superior airplanes can be designed, using modern concepts, with good assurance that they will meet their design performance in short field take-off and landing and in cruising speed and range. The challenge in both of these categories lies in producing the geometry demanded by the boundary layer."

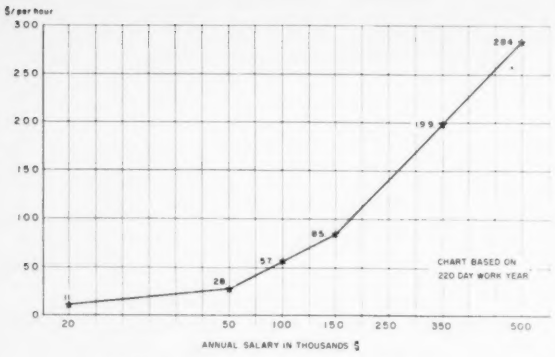
Mr. Raspet suggested that, "if we admit that distributed suction high lift augmentation can, with some development, double the usable lift coefficient with a relatively small power requirement and, consequently, a small weight increase, aerodynamicists will have to become more familiar with the concepts of the boundary layer." He added that "this can be accomplished by actually measuring the boundary layer on some airplanes in flight. . .[and] then, with these data and the fundamental laws of the boundary layer, specialists can actually compute the suction requirements for their airplanes. . . .Design can be accomplished analytically in this order:

"(1) Compute the potential pressure distribution around the airfoil for the two-dimensional case using a method such as Moriya's.

"(2) From this pressure distribution, compute the boundary-layer momentum thickness at the chord position where suction is to be started.

"(3) Using this value, compute the suction requirement using the Prandtl form of von Kármán's momentum equation.

"(4) From the suction requirements and the measured porosity of the perforations, compute the row spacing.



Executives' pay scale on an hourly basis.

"(5) From the pressure distribution and the total suction required, one obtains the air power required for moving the suction air. Introducing suction pump efficiency, one has the power required for the pump.

"For transmitting the power to the suction pumps, which are easily installed in the wing, a hydraulic transmission using variable displacement pumps on the engines was found most efficient and light, albeit expensive."

Speaking for "those of us working regularly in the business aircraft field," G. Edward Rice commended manufacturers for "foresight in continued development of aircraft" for business use. He added, however, that "we have wondered at the reasoning" of some major manufacturers who have "been willing to spend many millions of dollars competing in an air-line market of a few hundred jet or turboprop airplanes, yet showing reluctance to expend a fraction as much to develop an airplane" for business use.

As to the future, Mr. Rice quoted the General Aviation Facilities Planning Group forecast that in 1977 a quarter of all first-class business transportation in the 100 to 1,000-mile range will be in business aircraft and that a considerable upswing will occur in business aircraft flying greater distances. A business fleet of more than 50,000 aircraft valued at over $1 billion and flying more than 11 million hours yearly was forecast. He estimated that in 1977 multiengine business aircraft will outnumber air-line aircraft by at least seven to one. He added:

"There will be needs for an increasing number of single- and multiengine helicopters or other short take-off and landing aircraft, reciprocating single- and multi-engine aircraft with minimum cruising speeds of 230 m.p.h., single- and multiengine propeller turbine aircraft with minimum speeds of 400 m.p.h., and multi-engine turbojet aircraft in the 600 m.p.h. cruising speed class. Just as there are aircraft flying today that were flying in 1937, there will be aircraft flying in 1977 that are flying today. However, the majority of these aircraft will be built in the next two decades.

"It is believed that reciprocating engines will be used principally in the smaller and shorter range aircraft; propeller turbine engines in medium- to long-range aircraft, especially in sizes of over 20 passengers; and turbojets in high-speed long-range aircraft of under 20-passenger size. It is felt that the cost of larger jets will make their use generally prohibitive in business. On the other hand, shaft turbine engines with demonstrated reliability may find more widespread use in helicopters or the faster single-engine propeller-driven aircraft, as the operating efficiency of such engines improves."

The advantages of jet flight as an efficient and time-saving tool for the nations' businessmen was taken up by Major Gen. Sessums in a paper on "Executive Aircraft for Business and Military." He observed that, "when considerations are given to the high cost of operating a business that requires management of vast interests, it becomes evident that whenever one can save time, one saves money. As extensive travel can now be accomplished in hours, it is well to consider executive salaries in hours." (See accompanying figure.)

General Sessums said that, in considering jet operations, "one of the most appealing features is that of lowered costs. The time saved by the executive will ultimately be measured, of course, by the frequency of trips required and the distances involved. Jet fuel, although consumed at a greater rate per hour, costs approximately one third as much as aviation gasoline. With a saving in flight time for the distances covered, and cheaper costs of fuel, all operations should be more economical."

The General said that "jet maintenance is not a large problem, either, for there are fewer moving parts in a jet engine when compared with the complex piston engine. Jet engine reliability is improving steadily and is expected to continue its improvement. For instance, the J-47 engine is now approved for 1,200–1,400 hours between overhaul."

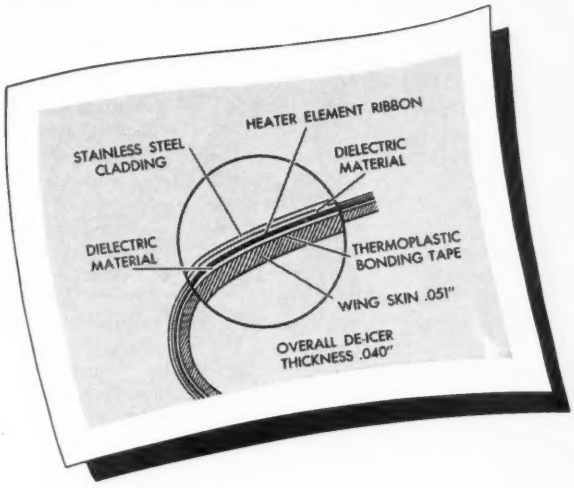
Three significant areas requiring attention, the General said, are "the noise problem, engine damage caused by ingestion of foreign objects, and the precise flight planning required for high-speed, high-altitude flight in jet aircraft.

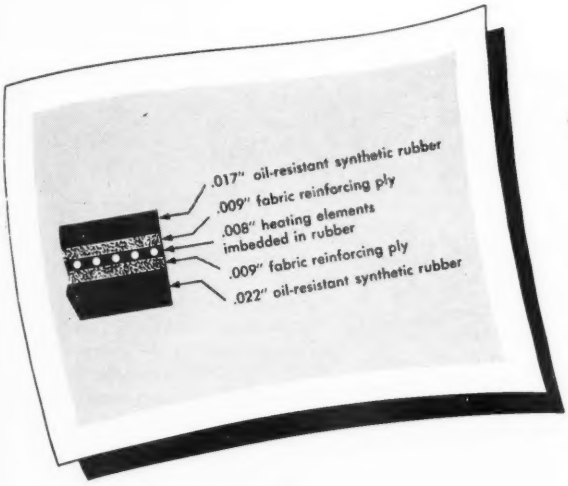
"The noise problem is receiving attention, but, to date, an acceptable device to suppress the high noise level generated during ground operations has not been developed. There are, of course, other problems that need attention. Among these are disposable-type oxygen masks that can be used in the event of explosive decompression at high altitude. These will be solved by those who recognize that the jet age is really here."

▲ ▲ ▲

B. F. Goodrich answers de-icing problems 3 ways

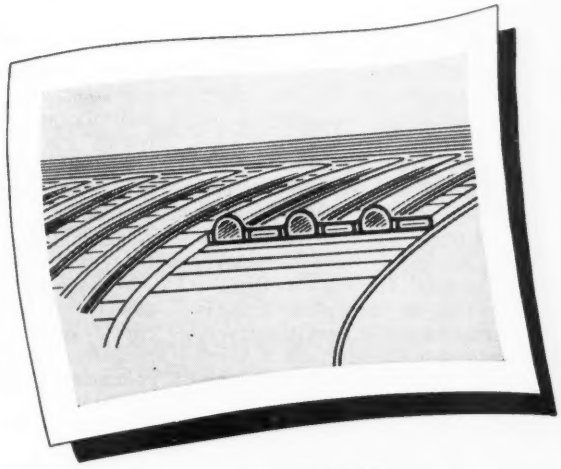
1. METAL-CLAD DE-ICERS – Lightweight B.F.Goodrich metal-clad De-Icers, as used on Boeing's KC-135 stabilizers, are highly resistant to abrasion and erosion from rain and hail. Ribbon-type electrical heating elements are sandwiched between layers of resin-impregnated glass fabric, topped by an exterior skin of stainless steel or other specified metal. Pre-shaped to the contour of the airfoil's leading edge, this De-Icer is attached with an adhesive bond.




.017" oil-resistant synthetic rubber
.009" fabric reinforcing ply
.008" heating elements imbedded in rubber
.009" fabric reinforcing ply
.022" oil-resistant synthetic rubber

2. HEATED RUBBER—B.F.Goodrich electrically heated rubber is a lightweight method of supplying heat for ice control in localized areas such as air intakes, cowls, propeller blades and spinners. Typical applications—Lockheed's Constellations and C-130. Heating elements arranged for proper heat pattern are sandwiched between thin, flexible sheets of rubber to fit complex curves or flat surfaces. Power density can be as high as 40 watts psi—overall thickness as small as .030".

3. PNEUMATIC DE-ICERS – B.F.Goodrich Pneumatic De-Icers offer the best method of ice removal for large areas. Small, rubber-reinforced fabric tubes, built in line with the air stream, inflate and deflate to snap off ice. This chordwise tube arrangement used on planes such as Lockheed's Super-Constellation series and the Grumman Albatross, smooths the flow of air over airfoil surfaces during the brief inflation period. This type of De-Icer is also being used on radomes because its pneumatic operation offers minimum interference with the radar signal.



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DATELINE world PROFESSIONAL NOTES AND REPORTS

Engineering and Scientific Briefs from Correspondents Around the Globe

(Continued from page 29)

theory of wave propagation in the ionosphere with actual physical conditions. The ground-fired rocket has not yet been developed. A Pi-type rockoon, with polystyrene balloon, will be used.

(4) Temperature and Wind. These are important measurements for the meteorologist. The K-V D-TW ground-fired rocket will be used. The nose section, called a dart, is not motorized and is separated from the second stage by an explosive charge. No comparable rockoon has been developed.

If possible, the Japanese hope to undertake two other projects: (5) Pressure of Atmosphere and (6) Geomagnetic Field.

In order to obtain the data, recovery is necessary, except where telemetering is used. The characteristics of the rockets are shown in Table 1 below.

The discussion of these rockets aroused considerable interest. They apparently will be small and cheap, and, if successful, the Japanese will have provided an economical and convenient way to explore the upper atmosphere. A height of 60 to 65 km. is expected.

Soviet Authors Report on Ferrous Alloys Work

◆ A research paper by K. P. Bunin and E. N. Pogrebnoy on the "Mechanism of the Effect of Hardening on Graphitization" presents some interesting data which are significant in that the authors are the only Soviet metallurgists besides I. A. Oding who even refer to the dislocation theory.

According to the authors, it is universally agreed that graphitization of steel and white iron is accelerated by prior hardening, but there is no agreement as to why. One school of thought considers that the effect of hardening is due to changes in the form, dispersion, and condition of the cementite and that the key factor in determining graphitization is the rate of carbon diffusion. The other view is that graphitization is related to the withdrawal by diffusion of matrix atoms away from the graphitization front—and that the accelerating effect of prior hardening is explained by the precipitation of graphite in microstructural inhomogeneities such as quenching microcracks and vacancies.

To resolve this problem, samples of a steel with about 0.93 per cent C, 0.38 per cent Mn, and 1.06 per cent Si were quenched from 1,100°C. They were then reaustenitized for varying periods at 900° to 1,200°C. and air cooled prior to graphitizing at 680°C. If the effect of hardening is determined by stresses in the carbide phase, carbide transformation, or degree of dispersion, even a short reaustenitizing treatment with subsequent slow cooling ought to remove the effect of prior hardening. On the other hand, according to the authors, if the effect of hardening is related to quenching microcracks and other microscopic inhomogeneities, a brief austenitizing treatment ought to have no effect in overcoming the accelerating effect of prior hardening on graphitization.

The results showed that reaustenitizing can remove the effect of prior hardening on graphitization. The required time is increased as the temperature of the second austenitizing is lowered. At 1,200°C., 10 to 15 min. were adequate; at 900°C., more than 4 hours were required.

Therefore, the main cause for the acceleration of graphitization by prior hardening appears to be defects (microcracks) and distortions of the matrix caused by hardening. Changes in dispersion and condition of the cementite can play only a secondary role.

Western investigators such as E. D. Harry have considered that this theory provides a plausible explanation of a number of factors involved in subcritical graphitization but that more proof was needed. Bunin is gradually accumulating the data necessary to bolster his hypothesis. It is now clear that the quenching cracks (easily visible at 500 X) shown in one of Bunin's previous articles must not be typical, as such cracks would not be expected to heal during a second austenitizing treatment. As was surmised at the time, he must be concerned with smaller-scale inhomogeneities, such as dislocations and incipient cracks, which could heal.

TABLE 1

Type	Diameter in Millimeters			Pay Load in Kilograms
	Dart	Main Rocket	Booster	
K-5 RS		122	330	7.5 to 8
K-4 C		128	330	6 to 7
K-V D-TW	80	122	330	13.5

U.S.S.R. P-57 Tank Equipped With Launcher for Rockets

◆ West German newspaper readers have learned of a hitherto undisclosed Soviet tank that has won for its developer—an engineer whose name was not disclosed—a prize of 100,000 rubles (about $25,000 at the official rate). *Der Flieger*, a Munich newspaper, reported that the sum was awarded by the Academy of Sciences, Moscow.

The tank, described with the designation P-57, reportedly is equipped with a launcher designed to fire rockets either for ground-to-air or ground-to-ground use. The report said the prototype vehicle had a launcher which could carry twelve rockets but that the production model has a 20-round launcher.

The item stated that the rounds would be fired with radar aid but did not indicate the type of fire control. Rocket performance was not reported except that maximum altitude was 26,200 ft.

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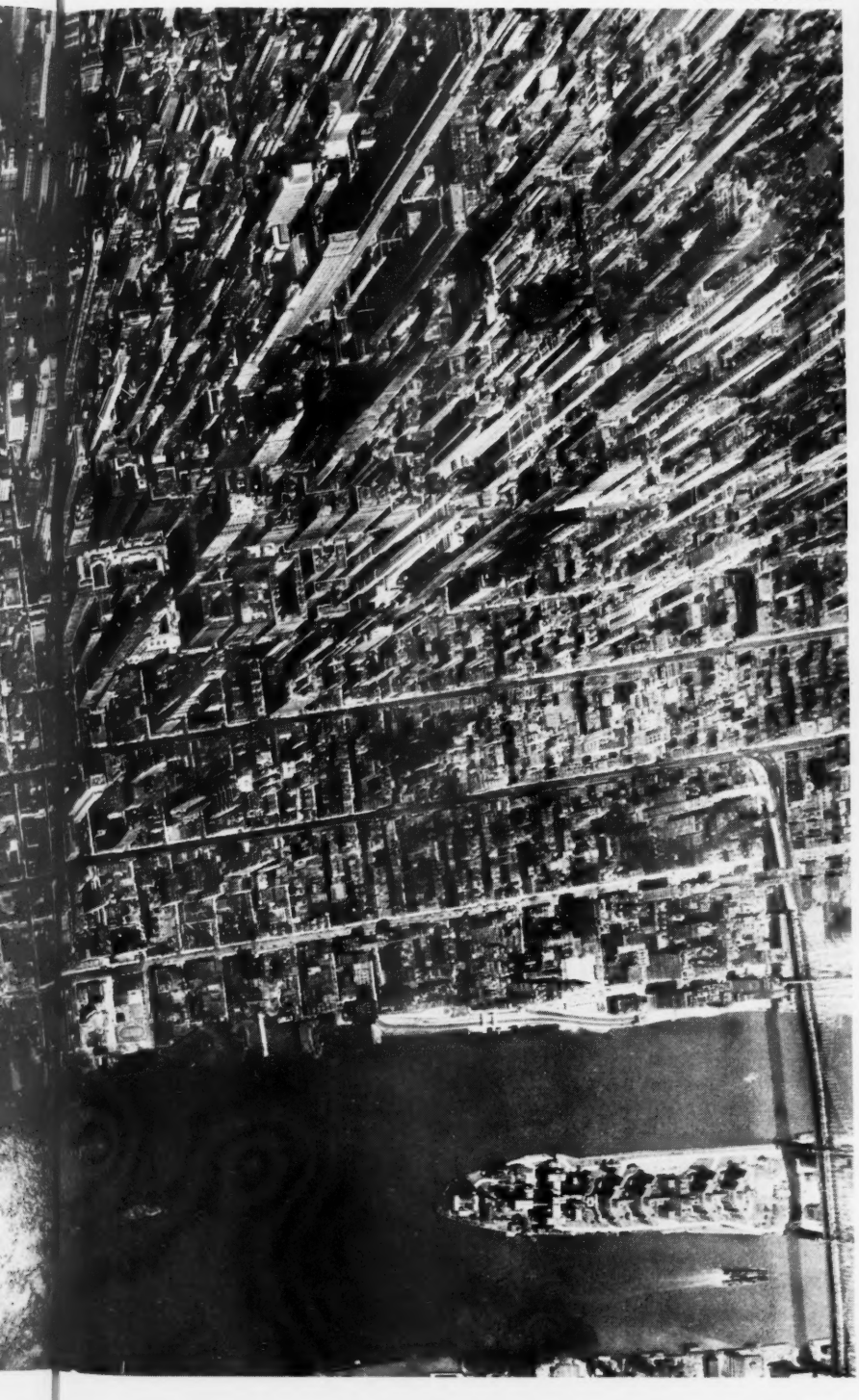
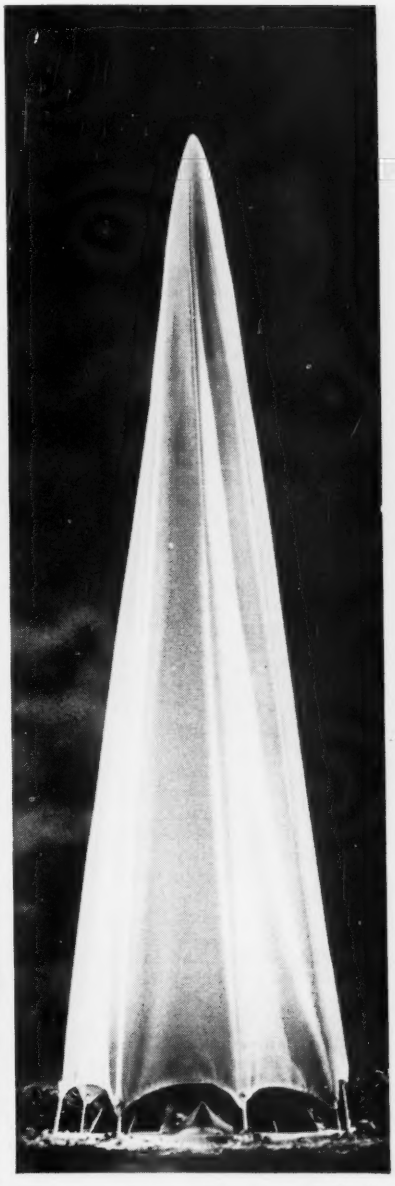
instruments against the tons of gravitational pull they meet in a rocket take-off tells much that will help protect passengers in a rocket ship. Improved aerodynamic design for supersonic fighters suggests more efficient airframes for rockets. The control system which will permit directing the Douglas *Thor* missile to a target 1500 miles away leads to controls for tomorrow's rocket ships.

Today, Douglas engineers work in fields ranging from atomic power to electronics, thermodynamics to acoustics. You see the results in skies around the world, in aircraft, rockets and missiles for all of our armed services.

COAST AND GEODETIC SURVEY





Thor, new intermediate range ballistic missile developed for the Air Force by the Douglas Aircraft Company is still a hush-hush project. Thor is designed to carry a thermonuclear warhead at meteoric speeds . . . when operational will supplement the manned bomber force of the Strategic Air Command. Douglas is now building three basic types of rocket and missile: air-to-air, ground-to-air, and ground-to-ground.

Depend on

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first in Aviation

IAS News (Continued from page 27)

• **Bendix Aviation Corporation. . .** Eclipse-Pioneer Division reports receipt of a $1.1 million order for PB-20 automatic flight control systems for Convair 880 commercial jet transports. . . .Malcolm G. Douglas has been appointed Director of Sales and Service, Montrose Division.

• **Cornell Aeronautical Laboratory, Inc.,** has developed a research aircraft, said to be capable of behaving like many other aircraft, termed a "variable stability and control airplane." Automatic control equipment is said to simulate changes in its physical characteristics. The Laboratory also reports development of new computing equipment for controlling interceptor groups against attacking enemy aircraft for fleet air defense. Six directors appointed to newly created divisions of the firm are William F. Milliken—Full-Scale Division; Franklin K. Moore—Aerodynamic Division; Harold A. Cheilek—Engineering Sciences Division; Robert H. Shatz—Systems Research Division; Robert S. Kelso—Experimental Facilities Division; and Seville Chapman—Physics Division. Five senior staff members were named heads of new departments.

• **The Dow Chemical Company** reports that big, higher-strength pellet extrusions are being produced successfully from its 13,200-ton extrusion press. James B. Reid has been named Magnesium Sales Manager in the firm's New York territory. The firm has established a new magnesium sales section to market magnesium and aluminum extrusions from its new press. John J. Clemens was named to head the section.

• **Fairchild Camera and Instrument Corporation** has announced the appointment of Charles J. Malven as Manager, West Coast Office, Industrial Camera Division.

A new supersonic flight suit, developed by the personal equipment subcommittee of the Industry Crew Escape Systems Committee, is modeled by W. H. Reineking, Design Specialist in charge of the Human Engineering Group, Convair (San Diego) Division, General Dynamics Corp. Protective features found in five other suits are combined into the one garment. The three-piece outfit is said to add up to 10 seconds' additional protection from burns, float the pilot face-up even when unconscious, reduce by one-third the time it takes for a pilot to don full personal equipment, and decrease the bulk of equipment.

• **Fairchild Engine and Airplane Corporation. . .**Guided Missiles Division has announced the appointment of John F. Hicks to the position of Assistant to the General Manager.

• **Federal Telecommunication Laboratories, Division of International Telephone and Telegraph Corporation,** has announced completion of a new "over-the-horizon" television-telephone link between Florida and Cuba (185 miles). In what the firm calls the key to a new era in international communication, microwaves are caromed off the troposphere to highly sensitive receiving antennas in Cuba. Other systems are under construction in Europe.

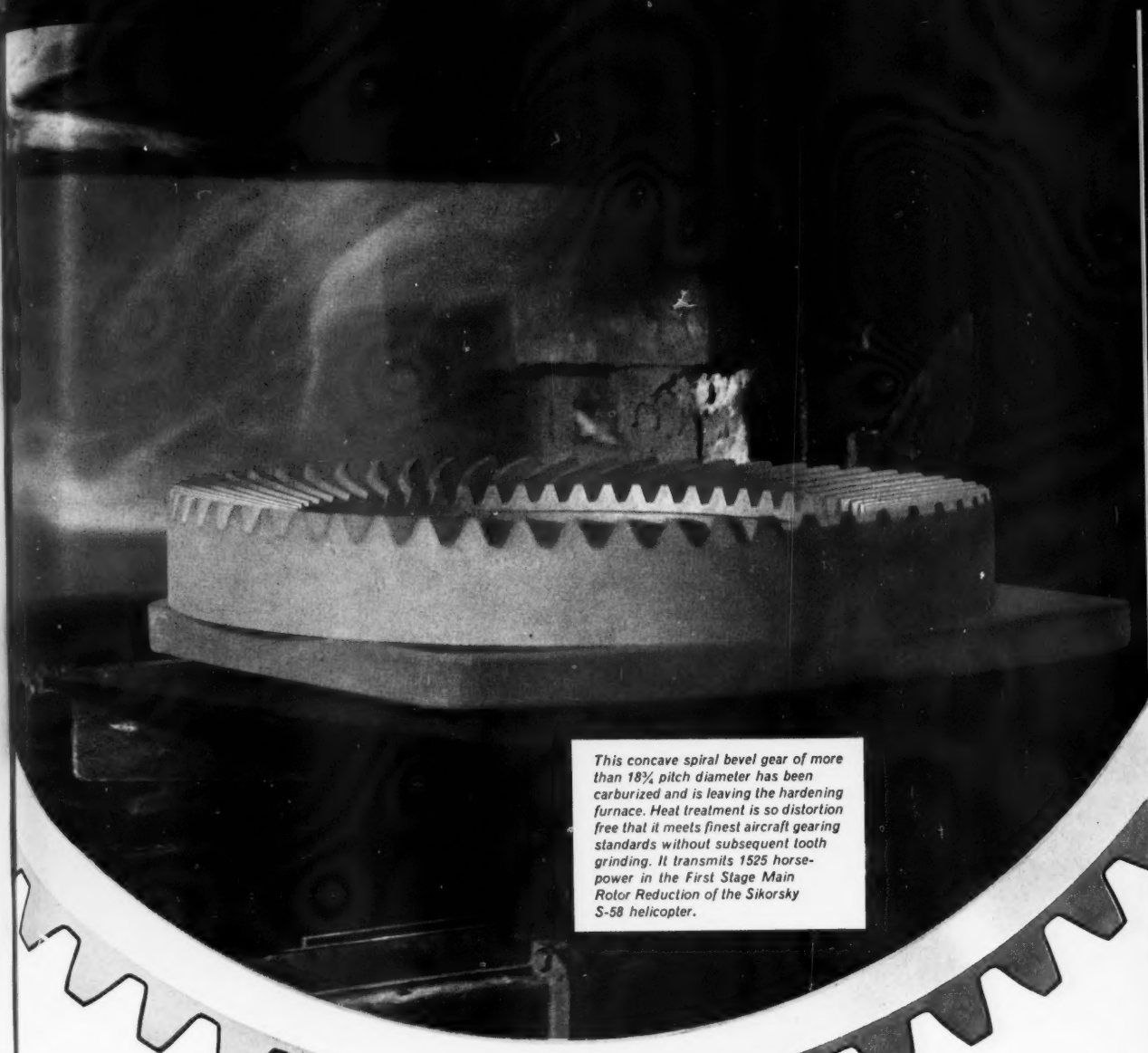
• **Flight Refueling, Inc.,** has announced it will manufacture a prototype probe and drogue aerial refueling system for the Martin P6M SeaMaster.

• **General Dynamics Corporation,** Convair Division, has announced rocket-sled seat ejection tests from a B-58 nose section. Three dummies, corresponding to the Hustler's three crewmen, have been ejected under conditions equivalent to the plane's supersonic speed. The division also announced that one of the world's largest template cameras will be used in the reproduction of templates for building the Convair 880. . . . A slotted-blade vane-axial fan, orginally developed by the Electric Boat Division for the atomic submarine U.S.S. "Skate," will be installed in the 880. It represents the lightest and most efficient air-conditioning unit ever fabricated for aircraft use, according to the firm. . . . Convair reports that four 880's have been purchased by the Brazilian air line Real-Aerovias.

• **General Electric Company** Research Laboratory has announced development of "four-square" silicon iron, said to be a new kind of sheet material designed to increase the efficiency of transformers, motors, and generators. The firm's Nobel-prize winner, Dr. Irving Langmuir, 76, died on August 16. . . . .Aircraft Gas Turbine Division engineers have developed a drilling and milling machine said to drill as many as 80 holes and mill 40 scallops automatically in a jet-engine tailpipe. They also have announced a polygon grinder said to grind internal and external spherical triangles, squares, ellipses, and circles. . . . Jerome T. Coe has been appointed Manager of Marketing, Silicone Products Department, Chemical and Metallurgical Division. . . .Defense Electronic Division has developed a booster unit which allows the separation of nose cone models from bodies during free flight tests. The significance, according to the firm, is that the principle employed in the inexpensive, small-scale range firings can be used for larger scale free flight. The operation permits aerodynamicists to study such effects as temperature, pressure, and noise on afterbody structures. . . .A new tube, the GL-6917, has been developed by the Electronic Components Division, Power Tube Department, to aid in preventing enemy radar-jamming. The division's Semiconductor Products Department has announced a new 85-watt silicon power transistor, said to have the highest power rating of any high-temperature transistor available.

• **General Precision Equipment Corporation** and A. V. Roe Canada Limited have agreed to a sales and manufacturing exchange covering a wide variety of ad-

Latest version of General Electric Company's Vulcan gun is this 30-mm. model using 50 per cent larger shells. Developed in the firm's Missile and Ordnance Systems Department for the Air Force, the gun is similar in operation to the Gatling gun invented in 1862. The earlier 20-mm. model arms the Lockheed F-104A.



This concave spiral bevel gear of more than 18¾ pitch diameter has been carburized and is leaving the hardening furnace. Heat treatment is so distortion free that it meets finest aircraft gearing standards without subsequent tooth grinding. It transmits 1525 horsepower in the First Stage Main Rotor Reduction of the Sikorsky S-58 helicopter.

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MOOG VALVE CO., INC. PRONER AIRPORT, EAST AURORA, NEW YORK

Research Laboratory, Paramus, New Jersey

Lockheed Aircraft Corporation's 16,200-hp. C-130B is being offered to air lines in a commercial air freight version with delivery scheduled for early 1960. Lockheed says the freighter will lift more than 22 tons for a nonstop distance of 1,750 miles. Cruising speed is said to be 350 m.p.h. at 30,000 ft. altitude. The freighter will have 13 1/2-ft. four-bladed propellers.

vanced technological products, according to an announcement from both companies. Included in the group are GPE affiliates Link Aviation, Inc.; Kearfott Company, Inc.; General Precision Laboratory Incorporated; and Askania Regulator Company. . . .GPL has announced a new "single unit" closed-circuit television camera with associated remote control accessories, Model PD-500, said to contain in one package the camera, camera circuitry, and camera controls within measurements of 5 in. width, 7 1/2 in. height, and 12 in. length. . . .Kearfott Company, Inc., has announced availability index stands with either a synchro or resolver bridge built as an integral part of the unit. Another new index stand (KT 426077) also available is said to hold and accurately locate the rotor shaft of a synchro to a desired angular position with respect to the stator. The firm's angle position indicator and servoamplifier (KT-427566-1) are said to form a servomechanism for accurate presentation of angular positions in terms of degrees and minutes, when properly interconnected. Kearfott also has announced a new radar test set containing both X-Band and C-Band in a portable cabinet. Arthur J. Olson, Jr., has been appointed Service Manager and Charles H. Berry, General Manager, Western Division.

• **G. M. Giannini & Co., Inc.,** has announced a new Binary Time Code Generatory, Datex DC-103, said to produce a serial output of one synchronizing pulse followed by eight bits of binary coded d.c. timing signals per second. The total number of unique binary coded time signals produced is 128, according to the announcement.

• **The Goodyear Tire & Rubber Company, Inc.** . . .Aviation Products Division has announced the appointment of Edward Wolf as Manager, Special Products Department, and William F. Burdick to the department staff. George Bachtel has been appointed to the newly created position of Administrative Assistant to the Division General Manager.

• **Grumman Aircraft Engineering Corporation** has announced the opening of offices in Washington, D.C. (the Continental Building, 1012 Fourteenth Street) under the direction of Vice-Admiral Joseph F. Bolger, USN (Ret.).

• **Kelsey-Hayes Company** has announced the purchase of Control Specialists, Inc., of Inglewood, Calif.—an engineering and research firm. Information on the company's various aviation divisions is listed in a new 32-page booklet available by writing to C. W. Duffy, Advertising Manager, Kelsey-Hayes Company, Detroit 32, Mich.

• **Kollsman Instrument Corporation** reports that it has stepped up production of synchrotel transmitters and servotorque units to meet increased activity in the manufacture of guided missiles. Redesign and standardization of parts have moved up delivery dates from 4 and 6 months to 60 days.

• **Lear, Incorporated . . .** LearCal Division has published a booklet called *ADF Stations* which lists data for more than 3,000 radio stations in the United States, Canada, and Mexico, suitable for automatic direction finding. Kenneth M. Miller has resumed his position as Manager of Engineering after a year on special assignment as Manager of Special Products. . . .Lear-Romec Division has announced availability of a dual-circuit heat exchanger for air-borne electronic equipment, Model RR20090, said to have a nominal heat dissipation rate of 6,000 watts total for both fluid circuits while maintaining a maximum liquid outlet temperature of 180°F. from sea level to 20,000 ft.

• **C. W. Lemmerman, Inc.,** has announced the election of Col. L. L. Morse as Vice-President and Director of the firm.

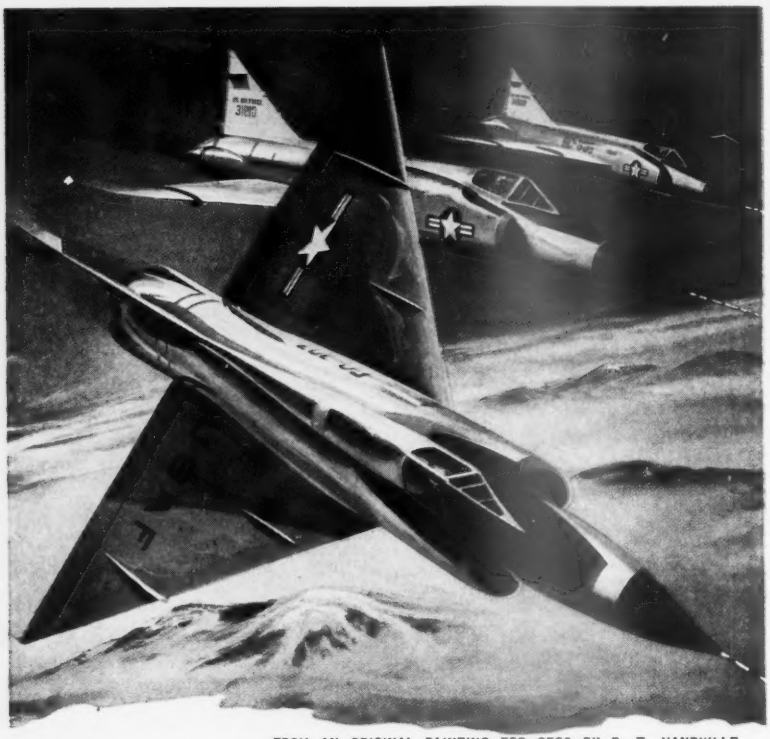
• **Lockheed Aircraft Corporation** Missile Systems Division and the Air Force have announced that numerous ballistic missile nose cones have been successfully tested on flights of the X-17. This missile, according to the announcement, has a flight lasting 6 min. and uses both a three-rocket second stage and a third-stage rocket to drive it downward through the atmosphere. Flight data are radioed to ground stations. Nuclear propulsion for missiles will be studied further with a new atom smasher which has been put into use at the firm's Palo Alto, Calif., nuclear laboratory. . . .California Division engineers report completion in record time of the JetStar, 10-passenger utility transport in the 500-m.p.h. class for the Air Force. The project was begun January 7, with no engineering drawings or specifications. The roll-out date 10 months later was met on the nose, according to Lockheed officials who said the average aircraft industry experience of 350 men on the project equaled 14.5 years. The aircraft is powered by two Bristol Orpheus engines mounted in pods attached to the rear of the fuselage. . . .Georgia Division has announced a new version of the Hercules, designated the C-130B, said to provide greater pay load, range, and utility. The division also announced that a C-130 flew across the country on two engines for test purposes. A tanker version of the Hercules has made successful flight tests, according to the division. Electra Notes: Vibration and shake tests have been conducted on the aircraft. Most of the essential shakedowns of the Allison 501 engines and Aeroproducts 606 propellers have been completed in a modified constellation. Polyethylene pins for insulation fasteners have cut aircraft weight 30 to 50 lbs. A new 100,000-lb. king-size pressure cooker is in use at the firm's Burbank plant building up trailing-edge wing assemblies through a metal-bonding method.

• **Marquardt Aircraft Company** has inaugurated a radio program "Engineering Report" heard 5 days a week, 7:25 to 7:30 a.m., in Los Angeles, Calif., on station KABC. The show features news and commentary on various technical and engineering developments in aircraft, missile, electronics, and allied industries.

• **The Martin Company** has been awarded the John Price Wetherill Medal of The Franklin Institute "in recognition of the intensive research, development, and manufacture of bonded structures." It is the first firm to be awarded the honor.

• **Minneapolis-Honeywell Regulator Company** has created a Military Products Group, said to combine all resources and military electronics experience into one of the largest sources in the country for research, engineering, and production capability. Stephen F. Keating, Vice-President, Aeronautical Division, has corporate responsibility for the new group's activities. His division, together with the firm's Ordnance and Boston divisions, form the main core of the group. The firm also reports that the first aircraft engine inlet diffuser control system to operate automatically during supersonic flight is in use on the B-58. The Aeronautical Division manufactures the system.

• **Norden-Ketay Corporation** has published a new bulletin on *Pick-Off and Sector Potentiometers for Aircraft and Missile Control Systems* which includes specifications and outline drawings. Bulletin #415 may be obtained by writing the firm at Commerce Road, Stamford, Conn. The company also has announced a new size



FROM AN ORIGINAL PAINTING FOR CECO BY R. T. HANDVILLE

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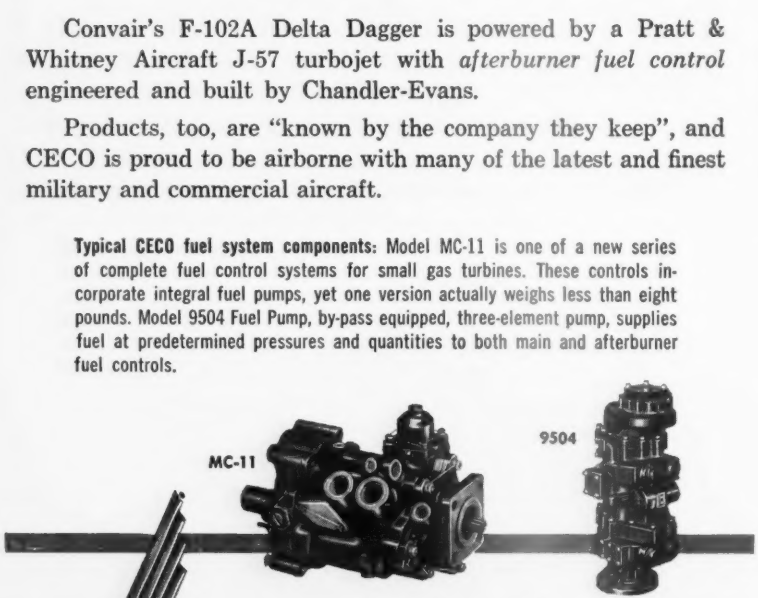
Convair's F-102A Delta Dagger is powered by a Pratt & Whitney Aircraft J-57 turbojet with *afterburner fuel control* engineered and built by Chandler-Evans.

Products, too, are "known by the company they keep", and CECO is proud to be airborne with many of the latest and finest military and commercial aircraft.

Typical CECO fuel system components: Model MC-11 is one of a new series of complete fuel control systems for small gas turbines. These controls incorporate integral fuel pumps, yet one version actually weighs less than eight pounds. Model 9504 Fuel Pump, by-pass equipped, three-element pump, supplies fuel at predetermined pressures and quantities to both main and afterburner fuel controls.



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Write Dept. 6G for an informative folder on CECO's new SMALL ENGINE FUEL CONTROLS, *or for folders on:* AFTERBURNER FUEL CONTROLS; AIRCRAFT PUMPS; UNITIZED FUEL CONTROL SYSTEMS.

15 resolver (10502V) said to provide a higher accuracy and impedance than previously obtainable. Jack Stadler has been appointed Director of Planning and Leslie M. Slote, Director of Personnel and Manager Development.

• **North American Aviation, Inc.** . . .Los Angeles Division has announced a method of gold-coating engine shrouds called reflectant noble metal coating and said to protect advanced jet aircraft engines from heat and corrosion on the inside. An exterior coating is said to reduce the amount of heat radiated outside onto components and structure of the aircraft. The division also has announced a new method of saving tools, man-hours, and titanium by overcoming the metal's tendency to crack in stretch-forming wherever there are rough edges or shear fractures. A new device mechanically pulls strips of titanium through a series of graduated cutting tools radiused to give the metal a smooth, rounded edge.

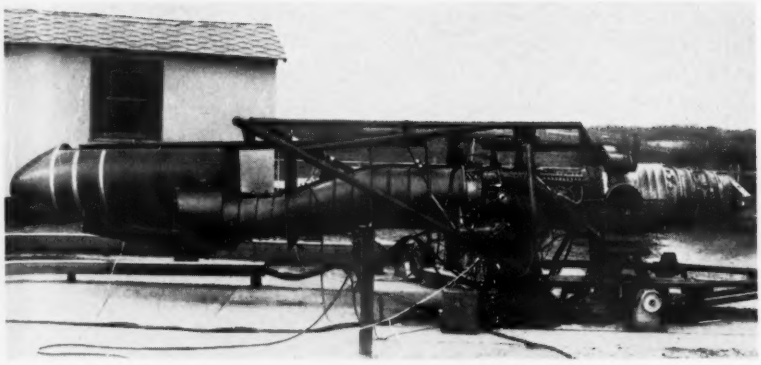
• **Northrop Aircraft, Inc.,** has announced the merger of its subsidiary Radioplane Company into the parent firm as a line division. . . .Alan C. Morgan has been elected to the newly created position of Vice-President of Contracts, Northrop Division. Paul H. Crews, former USAF security officer, has been appointed division Director of Plant Security and Protection.

• **Pan American World Airways, Inc.,** has begun direct nonstop service from New York to Rome which, the firm says, is the first in transatlantic air history. DC-76 aircraft will fly the 4,282-mile route in an estimated 13 hours and 15 min., three times a week. The air lines also announced like service to Frankfurt. The firm has begun polar-route flights from Seattle, Wash., and Los Angeles and San Francisco, Calif., to London and Paris, four times a week.

• **Piasecki Aircraft Corporation** has announced the appointment of John J. Hensel, production and manufacturing costs expert, as Administrative Coordinator of the firm's Delaware Division.

• **Reaction Motors, Inc.,** has announced that its new, all-attitude test stand at Lake Denmark, N.J., has been put into operation with the firing of one of the firm's latest rocket engine designs. Said to be the largest of its kind, the stand is reportedly capable of withstanding sustained thrust of one million pounds with the engine mounted in any flight attitude.

• **Servomechanisms, Inc.,** has acquired an evaporation technique process in obtaining certain assets of Silver Plastics Corporation, El Segundo, Calif. The technique effects the deposit of metals on electronic components. Servomechanisms designs and manufactures complex electromechanical control equipment and components for aircraft and missile applications. The company has made the same move involving Precision Components, Inc., and has incorporated that firm's advanced precision tachometer generator into the line of products of its Mechatrol Division. . . .A new brochure on the products, capabilities, and facilities of the firm's new Magnetics Division is available from the division at 1000 West El Segundo Blvd., Hawthorne, Calif.



A series of tests to determine compatibility of Westinghouse Electric Corporation's J-34-WE-46 jet engine and the North American Aviation T2J-1 inlet duct has been completed at the Westinghouse Flight Test Center. The firm's Aviation Gas Turbine Division will manufacture the engines for the Navy's T2J trainer.

• **Simmonds Aerocessories, Inc.,** Board of Directors has announced the election of Gerald J. McCaul as Vice-President, Contracts and Service, and Myron G. Domsitz, Vice-President, R&D.

• **Sperry Gyroscope Company Division of Sperry Rand Corporation** has announced development of a new self-contained gyro horizon said to provide attitude flight data accuracies approaching those obtained only with gyro-stabilized "platforms."

• **Thiokol Chemical Corporation** has issued a booklet on the firm's new liquid polymer LP-31, said to have the highest molecular weight of the liquid polysulfide polymers manufactured by the firm.

• **Trans World Airlines, Inc.,** has announced that the first of five Super G Constellation flight simulators has been installed at the firm's Kansas City, Kan., training center.

• **Union Carbide Corporation** has published a new booklet containing the latest properties information on Multimet alloy, used in aircraft metal-working applications. Copies may be obtained from Literature Distribution Section, Haynes Stellite Company, Division of Union Carbide Corporation, 30-20 Thomson Avenue, Long Island City 1, N.Y. . . .Linde Company division has introduced a new medium-pressure welding blowpipe reportedly capable of welding any metal thickness from 28 gage to 3 in. and handling heating jobs requiring total gas flows up to 1,500 cu.ft. per hour. The division is expanding its production facilities at Fontana, Calif., to increase the liquid oxygen and liquid nitrogen capacity of the plant by more than 100 million cu.ft. per month. . . . National Carbon Company division has announced a 7-year industrial expansion program to add nearly 100,000 tons of annual productive capacity at plants throughout the nation. C. E. Ford has been named to the newly created position of New Products Marketing Manager of the division. The Carbon Products Sales Department has been reorganized to provide better technical service to industrial customers.

• **Vickers Incorporated** has announced a new hydraulic ground-mobile jet-engine starter which is said to offer many advantages over existing starter systems. R. E. Esch, General Manager, International Division, has been elected a Vice-President of the company. Frank L. Moncher has been appointed Director, Engineering, Aero Hydraulics Division.

• **Vitro Corporation of America** has announced acquisition of Nems-Clarke, Inc., a firm engaged in design, development, and production in the fields of electronics, communications, mechanics, television, instrumentation, automation, and nucleonics. The firm is now an operating division of Vitro. Laurance S. Rockefeller and Robert W. Purcell have been elected to the board of directors

• **Western Gear Corporation. . .**Electro Products Division has announced the availability of a new miniature 12–16 vdc motor said to be capable of operating in dry nitrogen gas at 30 mm. of mercury pressure absolute for 200 hours. Designed for missile application, it is designated Model P2P11A. The firm has issued a new engineering catalog on *Rotary Electrical and Electronic Equipment,* Bulletin 5721, available from Glenn Malme, Western Gear Corporation, P.O. Box 182, Lynwood, Calif.

• **Westinghouse Electric Corporation** has announced availability of a new silicon in which the impurities are said to be less than one part in six billion. A joint development of Westinghouse, Siemens-Schuckert, and Siemens & Halske Companies in Germany, the new silicon is said to have single crystal properties ranging from 400 to 1,000 ohm-centimeters resistivity with a lifetime of 400 to 800 microsec. The firm's carrier-microwave department has announced completion of a new office building adjacent to the Halethorpe, Md., plant. John B. Graef has been named Manager, Aviation Industry Sales.

• **Weston Electrical Instrument Corporation, a Subsidiary of Daystrom, Inc.,** has added a new district sales office and repair facility in San Francisco, Calif., at 147 10th Street. The new facility includes high-precision test equipment for the calibration and repair of panel, switchboard, and portable instruments. Herman E. Held is District Manager.

MEMBERS ELECTED

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the Review.

Transferred to Associate Fellow Grade

Bradfield, Walter S., M.S. in Ae.E., Sr. Staff Scientist, Scientific Research Lab., Convair Div. (San Diego), General Dynamics Corp.

Bridgforth, Robert M., Jr., M.S. in Physical Chem., Sr. Group Engr., Power Plant Staff, Boeing Airplane Co.

Goodmanson, Lloyd T., M.S. in Ae.E., Proj. Engr., Boeing Airplane Co.

Kellner, Richard J., Proj. Engr., Weapons System Div., Radioplane Co.

Levy, Lawrence, M.S. in Ae.E., Pres., Allied Research Associates, Inc.

Rotelli, Ranieri L., B.S. in M.E., Proj. Engr., Boeing Airplane Co.

Steele, Crittenden P., B.S. in Ae.E., Proj. Engr., Boeing Airplane Co.

Elected to MEMBER Grade

Baker, Thomas F., B.S. in M.E., Head, Vibration and Flutter Section, NACA (Edwards AFB).

Batscha, Alexander P., B.S. in Ch.E., Propulsion System Analyst, AGT Div., General Electric Co. (Cincinnati).

Benveniste, Robert M., B.S. in Ae.E., Aerodynamicist, Boeing Airplane Co. (Renton).

Bottorff, Marion R., M.S. in M.E., Sr. Test Engr., Aero. Lab. Dept., Univ. of Southern California.

Brainard, Robert E., M.S. in Engrg., Staff Analyst, Summers Gyroscope Co.

Briggs, Cameron, B.S., Service Engr., Convair Div. (San Diego), General Dynamics Corp.

Brown, Eugene L., B.S. in Indus. Engrg., Aerodynamicist, Bell Helicopter Corp.

Clooney, Robert E., Sr. Engr., Airframe Design, Northrop Aircraft, Inc.

Dempsey, J. R., M.S. in Ae.E., Div. Mgr., Convair Div. (Astronautics, San Diego), General Dynamics Corp.

Ellenburg, George W., M.S. in Indus. Engrg., Mgr., Design Analysis, Rocket Engrg., Flight Propulsion Lab. Dept., General Electric Co. (Evendale).

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Gamage, Russell W., M.S. in Ce.E., Engrg. Specialist, Northrop Aircraft, Inc.

Gingo, Peter J., B.S. in Physics, Aerodynamic Engr., Propulsion Research Corp.

Gluhareff, Eugene M., B.S. in Ae.E., Pres. and Chief Engr., E. Gluhareff Helicopter Corp.

Gottfried, Freer R., B.S. in Engrg., Supvr., Flight Test Operations, Marquardt Aircraft Co.

Gray, Billy C., M.B.A., Lt. Col., Asst. Secy., Scientific Advisory Board, USAF (Washington, D.C.).

Hergenrother, Rudolf C., Ph.D. in Physics, Dept. Mgr., Raytheon Mfg. Co.

Huey, Homer D., B.S. in Ae.E., Tech. Director, Aviation Armament Lab., Naval Air Development Center (Johnsville).

Johns, David J., B.S. in Engrg., Tech. Officer, Sir W. G. Armstrong Whitworth Aircraft, Ltd.

Johnson, Henry A., Supvr., F-89 Service Engrg., Northrop Aircraft, Inc.

Lowe, John E., B.S. in C.E., Leadman, Boeing Airplane Co.

Kremzier, Emil J., B.S. in Ae.E., Sr. Thermodynamics Engr., Convair Div. (San Diego), General Dynamics Corp.

MacInnes, John N., B.S. in C.E., Naval Advisor to V-P, Engrg. & Military Relations, Ryan Aeronautical Co.

Mathewson, A. A., B.S. in M.E., V-P—Engrg., Petro Mechanics Research Div., Borg-Warner Corp.

Matlock, Robert W., B.S. in M.E., Chief Engr., Zenith Plastics Co.

McCormack, Gerald M., B.S. in M.E., Chief, 9 × 7 Ft. Supersonic Wind Tunnel, Ames Aero. Lab., NACA (Moffett Field).

Menin, J. Brian, Sr. Structures Engr., Lockheed Aircraft Corp. (Marietta).

Minutello, Raymond V., B.S. in M.E., Flight Test Engr., Convair Div. (San Diego), General Dynamics Corp.

Montgomery, John B., B.S. in Physics, General Mgr., Production Engine Dept., General Electric Co. (Evendale).

Peters, Brice G., B.S. in Engrg., Design Specialist Missile Systems Div., Lockheed Aircraft Corp. (Van Nuys).

Redd, Joseph W., Jr., B.S. in M.E., Asst. Flight Test Group Engr., Convair Div. (San Diego), General Dynamics Corp.

Shippen, William B., B.S. in M.E., Engr., Applied Physics Lab., The Johns Hopkins Univ.

Smith, Harry H., Chief Weight Engr., Blackburn and General Aircraft, Ltd.

Snowden, Earl W., B.S. in Ae.E., Sr. Structures Engr., Convair Div. (Ft. Worth), General Dynamics Corp.

Taylor, Clement F., B.S. in E.E., Engr., Flowmeter Advance Engrg., General Electric Co. (Lynn).

Turner, James R., M.S. in M.E., Research Engr., Ingersoll-Rand Co.

Wagner, Fred G., Sr. Aerodynamics Engr., Convair Div. (San Diego), General Dynamics Corp.

Younger, Dewey G., Jr., M.S. in M.E., Supvr., Structures, Missile Development Div., North American Aviation, Inc. (Downey).

Zarovsky, Jacob, B.S. in Ae.E., Guided Missile Proj. Dir., U. S. Army Ordnance Corp. (Redstone Arsenal).

Transferred to MEMBER Grade

Francis, James E., M.S. in Ae.E., Aerodynamic Specialist, General Electric Co. (San Romon).

Mayes, Joe F., B.S. in Ae.E., Aerodynamics Engr., Convair Div. (Ft. Worth) General Dynamics Corp.

O'Clock, Robert, M.S. in Ae.E., Maj., Student, Air Command & Staff College, USAF (Maxwell AFB).

Rastiello, Michael K., B.S. in Ae.E., Aerodynamicist, North American Aviation, Inc. (Columbus).

Robison, William C., Aero. Engr., Capt., B-58 Proj. Engr., USAF (Wright-Patterson AFB).

Schramm, Ned, Jr., B.S. in Engrg. & Military Tactics, Lt. Col., Graduate Student, Univ. of Southern California, USAF.

Spak, Michael, B.S. in Ae.E. Structures Engr., Douglas Aircraft Co., Inc. (Santa Monica).

Tripp, Warren J., B.S. in Ae.E., Engr., New Product Planning, General Electric Co. (Evendale).

West, Robert E., B.S. in Ae.E., Flight Test Engr. "A," Boeing Airplane Co.

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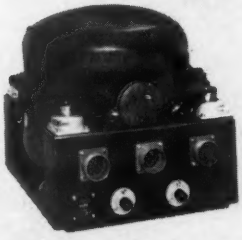
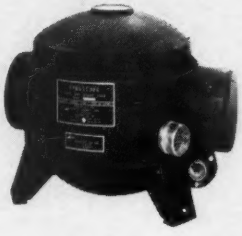


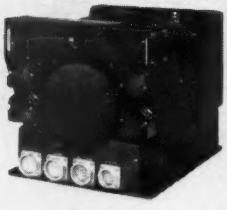
KEARFOTT has been engaged in the development, production and flight testing of Inertial Systems and their components for over 7 years. Their leadership in the field of lightweight, high precision Inertial Guidance Systems for aircraft and missiles has been proved by performance. The instrument shown here is a typical KEARFOTT inertial platform.

CENTRAL GYRO REFERENCE SYSTEMS



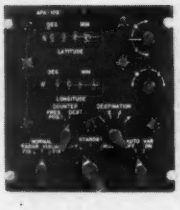
Based on this 3 gyro, 3 gimbal stable platform weighing only 25 pounds, precise vertical reference (2 milliradians) under all dynamic conditions is guaranteed. This system also serves as an all-latitude compass system with 1° per hour random drift rate. Its performance is substantiated by the hundreds of systems in operation today.

LIGHTWEIGHT ALL ATTITUDE COMPASS AND VERTICAL REFERENCE SYSTEMS



Based on a 29.5 pound 3 gyro, 4 gimbal platform, Kearfott All Attitude Compass Systems provide continuous steering signals throughout a LABS maneuver. In addition to the compass features of the U.S.A.F. J4 System, precise vertical reference for fire control, autopilot and radar stabilization is available. Proved by 2 years' service in the field. Total system weight—57 pounds.

GREAT CIRCLE NAVIGATION COMPUTERS



Kearfott's great circle dead reckoning computer systems, continuously compute and display present position, course and distance to a primary and 3 alternate destinations, latitude and longitude of the destination points. Ground track is also indicated. Range: 2000 miles, speed range: 2000 knots. Extensive flight tests have confirmed the following accuracies: Present position—1 mile or ½% of distance traveled; Distance—1 mile or ½%; Course: ½°.

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Elected to Associate Grade

Carlson, Robert H., B.S. in Bus. Admin., Sales Engr., Waldorf Instrument Co., Div. of F. C. Huyck & Sons.

Coates, Charles R., Jr., B.S. in Ae.E., Aero Research Engr., U. S. Naval Air Missile Test Center (Point Mugu).

Conant, James D., M.A. in English Language and Lit., Asst. to Chief Engr., Airframe and Mech. Design, Northrop Aircraft, Inc.

Cramer, Willis T., B. of Metallurgical Engrg., Staff Metallurgical Engr., American Steel & Wire Div., United States Steel Corp.

Eustis, Richard S., Jr., B.S., Field Engr., Pacific Scientific Co.

Gibson, David J., B.S. in Math. & Physics, Tech. Engr., General Electric Co. (Lynn).

Wensel, Harlan A., B.S. in Ae.E., Convair Div. (Ft. Worth), General Dynamics Corp.

Transferred to Associate Grade

Alves, Moses L., B.S. in Ae.E., Engr., Dynamics, North American Aviation, Inc. (Columbus).

Attinello, Joseph J., B.S. in Ae.E., Assoc. Design Engr., Lockheed Aircraft Corp. (Burbank).

Barber, Robert E., B.S. in M.E., Jr. Engr., United Aircraft Corp. (E. Hartford).

Battey, Robert V., B.S. in Ae.E., Aerodynamics Engr., Convair Div. (Astronautics, San Diego), General Dynamics Corp.

Beachler, John C., B. of Ae.E., Aeronautical Engr., North American Aviation, Inc. (Columbus).

Benenson, David M., Ph.D. in Ae.E., Research Engr., Research Labs., Westinghouse Electric Co. (Pittsburgh).

Bennet, Robert M., B.S. in M.E., Aero. Research Engr., NACA (Langley Field).

Benthul, Harless R., B.S. in Ae.E., Lt., Maintenance Supvr., SAC, USAF (Biggs AFB).

Bialla, Paul H., B.S. in Ae.E., Assoc. Engr., Douglas Aircraft Co., Inc. (Santa Monica).

Bithell, Robin A., B.S. in Ae.E., Aero. Research Engr., Ames Aero. Lab., NACA, (Moffett Field).

Carpenter, Stanley H., B.S. in Engrg., Maj., Exec. Officer, U. S. Marine Corps. (Edenton).

Clement, Darrell L., Assoc. Engr., McDonnell Aircraft Corp.

Coleman, Ronald S., B.S. in M.E., Research Engr., Intern, Lewis Flight Propulsion Lab., NACA (Cleveland).

Consalvo, Dante V., B.S. in Ae.E., Devel. Engr., H. K. Porter, Inc.

Cooper, Donald L., B.S. in Ae.E., Assoc. Engr., McDonnell Aircraft Corp.

Crafton, Robert S., Assoc. Engr., Convair Div. (Astronautics, San Diego), General Dynamics Corp.

Cravens, Rodney P., B.S. in Ae.E., Assoc. Design Engr., Convair Div. (Astronautics, San Diego), General Dynamics Corp.

Cummings, Benjamin E., M.S. in Ae.E., 2nd Lt., Aero. Engr., Air Force Flight Test Center, USAF (Edwards AFB).

Davis, Richard L., B.S. in Ae.E., Design Engr., Cessna Aircraft Corp.

DeLuca, Patrick J., B.S. in Ae.E., Sr. Stress Analyst, Emerson Electric Mfg. Co.

Douglas, J. R., B.S. in Ae.E., Capt., Proj. Engr., USAF (Kirtland AFB).

Dunlap, Duane F., B.S. in Ae.E., Assoc. Engr., Convair Div. (San Diego), General Dynamics Corp.

Erickson, John W., B. of Ae.E., Assoc. Engr., Aerophysics, Convair Div. (San Diego), General Dynamics Corp.

Estol, Conrado J., B.S. in Ae.E.

Farrell, John F., Jr., B.S. in Ae.E., Assoc. Engr., Arma Div., American Bosch Arma Corp.

Fenning, Robert D., B.S. in Aviation Tech.

Frahm, James R., B.S. in M.E., Engr. "1," Aircraft Nuclear Prop. Dept., General Electric Co. (Evendale).

Fromme, Charles F., Jr., B. of Ae.E., 2nd Lt., Maintenance Officer, Aero. Repair Branch OIC, USAF (March AFB).

Fulton, James P., B.S. in Ae.E., Weight Control Engr., Douglas Aircraft Co., Inc. (Tulsa).

Grunz, Richard H., Assoc. Engr., The Martin Co. (Denver).

Hall, Donald A., Jr., B.S. in Engrg., Jr. Engr., Ryan Aeronautical Co.

Hanks, Richard A., B. of Ae.E., Assoc. Research Engr., Boeing Airplane Co.

Hansen, John C., B.S. in Ae.E., Asst. Engr., United Aircraft Corp.

Harmon, Roland F., Jr., B.S. in Ae.E., Detail Engr., Cessna Aircraft Co.

Hartofilis, Stavros A., B.S. in Ae.E., Assoc. Engr., The Martin Co.

Holgren, Marvin A., B.S. in Ae.E., Lt., Maintenance Officer, NAS, U. S. Navy (Alameda).

Honeywell, Earl E., B.S. in Ae.E., Aerodynamics Engr., Convair Div. (Pomona), General Dynamics Corp.

Hutchinson, Rodney B., Assoc. Engr., Convair Div. (Astronautics, San Diego), General Dynamics Corp.

Kastner, Thomas M., M.S. in Ae.E., Lt., Aviator, Aircraft Maintenance Officer, U. S. Navy (U.S.S. "Essex").

Kolacz, Paul A., B.S., in Ae.E., Assoc. Engr., Northrop Aircraft, Inc.

Kottock, Stanley, B.S. in Ae.E., Assoc. Engr., Douglas Aircraft Co., Inc. (Los Angeles).

Kutschenreuter, Paul H., B. of Ae.E., 2nd Lt., Engr., ARDC U. S. Air Force, (Wright-Patterson).

Ladden, Richard M., B.S. in Ae.E., Engr., Propeller Div., Curtiss-Wright Corp. (Caldwell).

Lewellen, William S., B.S. in Ae.E., Graduate Student, Cornell Univ.

Lewis, Clarence A., Jr., B.S. in Ae.E., Jr. Engr., Curtiss-Wright Corp.

Mallick, Donald L., B.A. in N.E., Aero. Research Pilot, NACA (Langley Field).

McCoy, John C., B.S. in Ae.E., Lt., Graduate Student, U.S. Navy, California Institute of Technology.

McKenna, Charles M., Jr., B.S. in Ae.E., Assoc. Research Engr. "A," Boeing Airplane Co.

Ness, Mahlon, O., B.S. in Ae.E., Assoc. Engr., Lockheed Aircraft Corp. (Burbank).

Neville, Thomas J., Capt., Aero. Engr., Arnold Engineering Development Center, USAF (Tullahoma).

Novicki, John G., B.S. in Ae.E., Engr., Pratt & Whitney Aircraft Div., United Aircraft Corp.

Nowlin, William D., B.S. in Ae.E., Assoc. Engr., The Martin Co. (Orlando).

Olsen, Paul T., Tech. Asst., Bell Telephone Laboratories (Whippany).

Pasyanos, Emanuel N., B.S. in Ae.E., Aero. Engr., Grumman Aircraft Engineering Corp.

Paulson, Richard R., B.S. in Ae.E., Assoc. Engr., Flight Test, Lockheed Aircraft Corp. (Burbank).

Pestrichella, Alex A., B.S. in Ae.E., Lt., Aircraft Maintenance Officer, USAF (Chanute AFB).

Peterson, Charles N., B.S. in Ae.E., Engrg. Trainee, Missile Operations, Chrysler Corp.

Pritchard, Edgar B., B.S. in Ae.E., Graduate Student, Virginia Polytechnic Institute.

Rae, William H., Jr., B.S. in Ae.E., Asst. Supvr., Wind Tunnel, Univ. of Washington.

Richards, Homer K., Jr., B.S. in Ae.E., Lt., Heavy Attack Pilot, U.S. Navy (Whidbey Island).

Rigalo, Donald J., B.S. in Ae.E., Staff Member, Sandia Corp.

Riviere, Rene R., B.S. in M.E., Assoc. Engr., Northrop Aircraft, Inc.

Ross, Thomas H., B.S., Lt., Naval Aviator, U. S. Navy (Albuquerque).

Shutak, Robert J., B.S. in Aviation Tech., Student Trainee, Republic Steel Corp.

Siegele, Dale H., B.S. in Ae.E., Assoc. Engr., Douglas Aircraft Co., Inc. (Santa Monica).

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(Continued on page 153)

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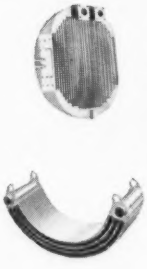

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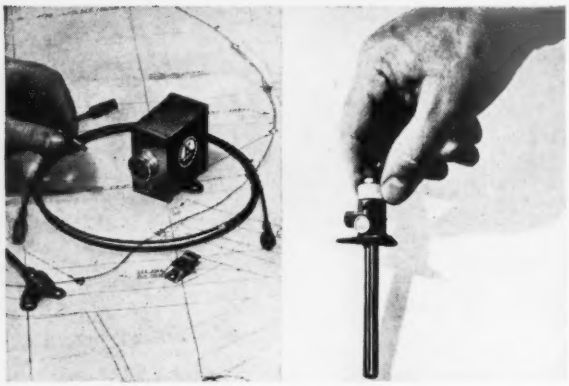

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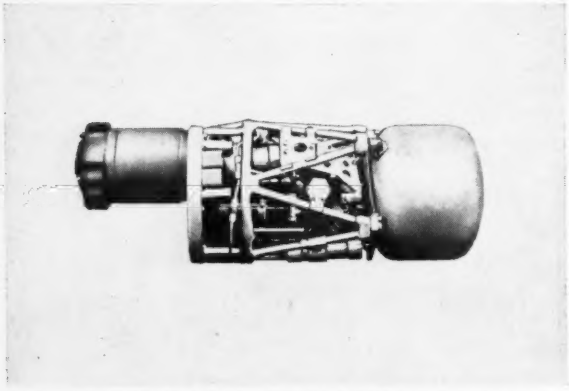

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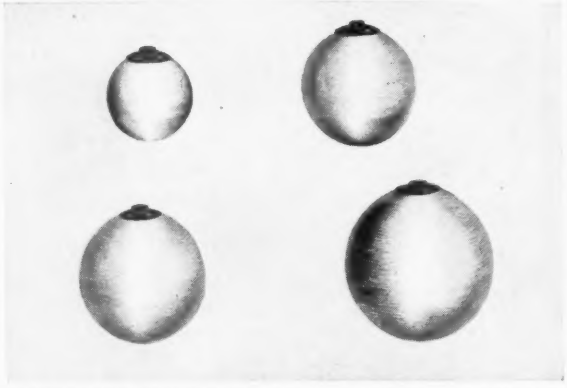

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Acoustics, Sound, & Noise

Hushing the Jet. Alex Dawydoff. *Flying*, Aug., 1957, pp. 30, 92.

Control of Airborne Sound by Barriers. Jack B. C. Purcell. *Noise Control*, July, 1957, pp. 20–26, 56, 58.

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Estimation of Incremental Pitching Moments Due to Trailing-Edge Flaps on Swept and Triangular Wings. Appendix A—**Use of the Basic Load Line as the Reference Sweep Line for Determining Local Centers of Pressure.** Appendix B—**Sample Calculations for an Aspect-Ratio-2 Triangular Wing with a Full-Span, Constant-Chord, Plain Flap Deflected 10°.** Harry A. James and Lynn W. Hunton. *U.S., NACA TN 4040*, July, 1957. 31 pp. 80 refs. Method employing the span-loading theory together with two-dimensional airfoil data adjusted for the effects of sweep, with applications demonstrated for 58 cases covering various types of flaps on wings having a wide range of sweep, aspect ratio, and taper ratio.

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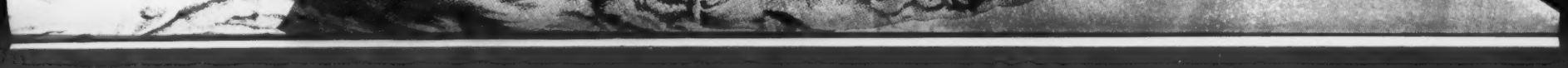

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Motion of Newtonian Liquid Between Rotating Coaxial Cylinders in the Presence of Thermal Processes Affecting the Viscous Properties. T. Ia. Gorazdovskii and S. A. Regirer. *Sov. Phys. - Tech. Phys.*, No. 7, 1957, pp. 1,493–1,502. 18 refs. Translation.

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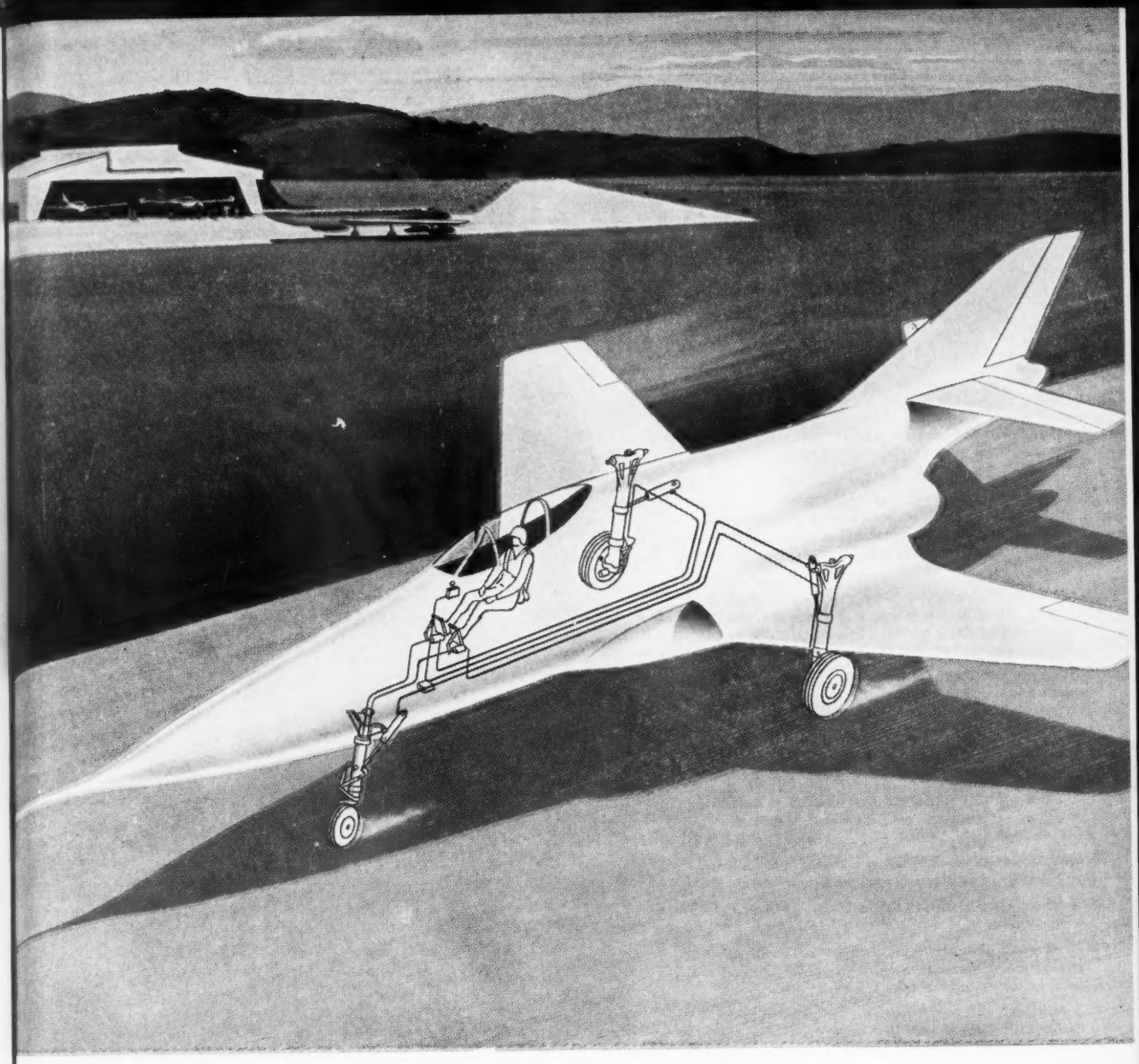
O Postroenii Ploskogo Sopla po Raspredeleniiu Sverkhzvukovykh Skorostei Vdol' Stenok. G. A. Dombrovskii. *AN SSSR Otd. Tekh. Nauk Izv.*, Mar., 1957, pp. 163, 164. In Russian. Evaluation of the design of a plane nozzle taking into account the supersonic velocity distribution along the walls.

Performance

Some Results of Comparison of Model and Full-Scale Spinning Tests. A. J. Marx. (*NATO AGARD Wind-Tunnel and Model-Testing Panel Meeting, Rome, Feb. 20–25, 1956.*) *NATO AGARD Rep. 26*, Feb., 1956. 9 pp. Investigation using the Fokker S-11 preliminary trainer.

The Subsonic Static Aerodynamic Characteristics of an Airplane Model Having a Triangular Wing of Aspect Ratio 3. I—Effects of Horizontal-Tail Location and Size on the Longitudinal Characteristics.

(*Continued on page 115*)



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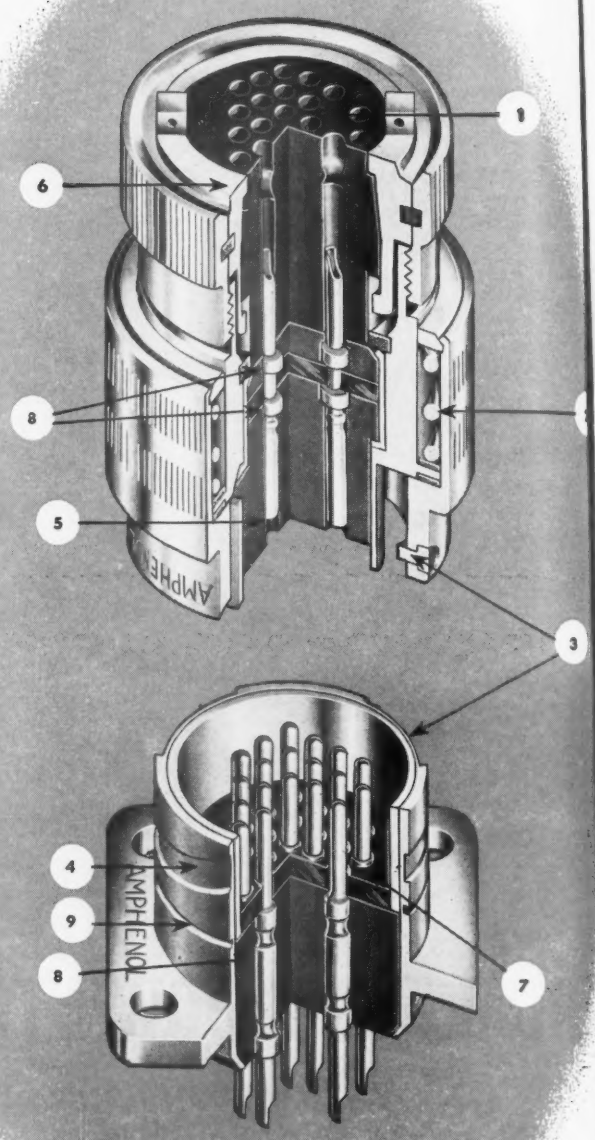

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ACOUSTICS, SOUND, & NOISE

A NEW CONCEPT IN THE DESIGN OF JET ENGINE MUFFLERS AND TEST CELLS. E. J. Richards and D. J. Evans. RAeS J., Sept., 1957, pp. 619-630. 16 refs. Description of the concept which suggests that a relatively small spreader can be added behind a jet nozzle to change the shape of the jet from circular to a long annular slot and thus to obtain a frequency rise suitable for reducing low-frequency noise. Since high-frequency noise is more easily attenuated than low-frequency noise, the possible resulting increase in the former does not significantly diminish the method's effectiveness. Tests are described on one particular version which gives an attenuation in the low-frequency range of 20 db. It is shown that the back pressure on the engine is negligible, even with a cooling flow equal to the mass flow. Other applications are discussed and tested, while suggestions for full-scale installations are made.

AERODYNAMICS

Aerothermodynamics

TURBULENT TRANSPORT OF HEAT AND MOMENTUM FROM AN INFINITE ROUGH PLANE. T. H. Ellison. J. Fluid Mech., July, 1957, pp. 456-466. 17 refs. Application of equations for the turbulent energy, the mean square temperature fluctuation, and the covariance of the temperature and vertical velocity, to derive a series of relations between the turbulent intensities and the Austausch coefficients. One of these relations indicates that the flux form of the Richardson Number cannot exceed a critical value which is about 0.15. It follows that in highly stable conditions the buoyancy forces have little direct effect on the turbulent energy balance, their action being primarily to cause a reduction in the scale of the motion and some change in its structure.

HYPERSONIC FLIGHT WITHOUT OVERHEATING. I - FRICTION HEAT ABSORPTION AND THRUST GAIN BY USE OF COOLANT-FUELS. L. Greiner, I. Michelson, and J. Rabinowicz. Odin Assoc. Rep. 100-2 (AFOSR TN 57-374) [AD132448], June, 1957. 55 pp. 14 refs. Study of coolant-fuels considering both the propellant and missile aerodynamics. The propellant study contemplates the ability of fuels to absorb heat and the impulse gains achieved thereby. A method is presented for estimating aerodynamic friction heating and the extent of heat transfer to the coolant-fuel as functions of the missile speed, configuration, flight plan, and state of the boundary layer. It is found that cooling, which reduces equilibrium temperatures to manageable limits, can also be made to increase the energy content of suitably selected coolant-fuels by as much as 50 per cent.

Boundary Layer

APPROXIMATE METHODS FOR PREDICTING SEPARATION PROPERTIES OF LAMINAR BOUNDARY LAYERS. N. Curle and S. W. Skan. Aero. Quart., Aug., 1957, pp. 257-268. 11 refs. Application of some new solutions for steady, incompressible, laminar boundary-layer flow, obtained by Görtler, to evaluate the two methods due to Thwaites and Stratford. A modification of Stratford's criterion for separation is given, along with modified numerical functions for the Thwaites method of predicting the main characteristics of the boundary layer over the whole surface.

DECOLLEMENT LAMINAIRE EN TROIS DIMENSIONS SUR UN OBSTACLE FINI. E. A. Eichelbrenner. France, ONERA Pub. 89, 1957. 37 pp. In French. Study of three-dimensional laminar separation on a finite obstacle based on geometrical considerations and on the hypothesis of regularity in the viscous fluid, including historical development of the problem, numerical application, and experimental verifications.

SOME NOTES ON SHOCK-WAVE BOUNDARY-LAYER INTERACTIONS, AND ON THE EFFECT

OF SUCTION ON THE SEPARATION OF LAMINAR BOUNDARY LAYERS. K. N. C. Bray. Gt. Brit., ARC CP 332, 1957. 11 pp. BIS, New York, $0.36. Review of the theory of Crocco and Lees and applications of this theory to the problem of shock-wave and boundary-layer interactions. The same method is then applied to the problem of estimating the extent to which critical Mach Number effects on a wing can be delayed by boundary-layer suction. It is found that a sucked boundary layer may require almost three times as big a disturbance as an unsucked one, in order to cause separation.

Control Surfaces

AN EXPERIMENTAL INTRODUCTION TO THE JET FLAP. N. A. Dimmock. Gt. Brit., ARC CP 344, 1957. 68 pp. BIS, New York, $1.80. Tests on two-dimensional airfoils, each having a 12.5 %-thick elliptical cross section with a narrow full-span jet slot at the trailing edge - the jet deflections being 90° and 31.4°, respectively. Results agree satisfactorily with Stratford and Davidson's theoretical predictions. Support is given to the thrust hypothesis in that the measured thrust is greater, under appropriate conditions, than the reaction component from the deflected jet. The losses in the system are considered, including those due to Reynolds Number and jet-entrainment effects. The influence of ground proximity on the lift and center of lift of the 31.4° model is measured at zero incidence, and a tentative empirical expression is suggested for the pitching-moment coefficient.

Fluid Mechanics & Aerodynamic Theory

ANALYSIS OF A VECTOR FIELD AND SOME APPLICATIONS TO FLUID MOTION. W. J. Duncan. Aero. Quart., Aug., 1957, pp. 207-214. Presentation of a method applicable for a vector field in which the basic concept is the field line. Analysis covers the special cases of line force, streamline, and vortex line. Simple relations are obtained for the rates of change of certain quantities along the tangent, principal normal, and binormal of the field. The applications to fluid motion are based on identifying the general vector of the theory with the instantaneous vorticity vector. The applications are easiest when the motion is steady and they cover an extension of Bernoulli's theorem to viscous fluids.

THE GROWTH AND DECAY OF SONIC DISCONTINUITIES IN IDEAL GASES. T. Y. Thomas. J. Math. & Mech., July, 1957, pp. 455-469. Analysis of an ideal gas which is devoid of viscosity and thermal conductivity, and whose behavior is governed by a system of nonlinear differential equations consisting of the equation of motion, the equation of continuity, and the equation for the entropy condition.

THE MOTION OF SLIGHTLY VISCOUS FLUID BETWEEN TWO NON-COAXIAL ROTATING CYLINDERS. W. W. Wood. Australia, ARL Rep. A. 103, Apr., 1957. 29 pp. Analysis of a viscous motion whose governing equations may, in principle, be solved exactly. The asymptotic behavior of the solution is derived for the case when the fluid viscosity is small, and a procedure is formulated by which the higher order corrections to the boundary-layer approximation may be determined. In as much as the streamlines are closed, the results bear particularly on closed flows.

HITZDRAHTMESSUNGEN IN EINER AUFGESPALTENEN KÁRMÁNSCHEN WIRBELSTRASSE. O. Wehrmann. DVL Bericht No. 43, July, 1957. 31 pp. 11 refs. Westdeutscher Verlag, Köln & Opladen. In German. Description of hot-wire measurements of von Kármán's vortex street split by a thin wall. Includes presentation of three types of criteria for hot-wire signals generated by the vortices, and determination of the velocity distribution of real vortices.

LINEARIZED TRANSONIC FLOW ABOUT SLENDER BODIES OF REVOLUTION AT ZERO INCIDENCE. P. F. Maeder and H. U. Thommen. Brown U., Div. Eng. TR WT-25 (AFOSR TN 57-384) [AD 132459], July, 1957. 112 pp. 12 refs. Derivation of an approximate solution to the differential equation for flow around isolated slender bodies of revolution. Some simple choices for the only remaining transonic parameter are discussed, and the theory is applied to parabolic bodies and half-bodies of revolution. Drag measurements on parabolic bodies of revolution for different sizes are carried out using different types of partly open tunnel walls.

OBTEKANIE TEL IDEAL'NYM GAZOM PRI BOL'SHOI SVERKHZVUKOVOI SKOROSTI. G. G. Chernyi. AN SSSR Otd. Tekh. Nauk Izv., June, 1957, pp. 78-85. Development of an analytical method for calculating the supersonic flow of ideal gas around axisymmetric bodies and two-dimensional profiles. The method is based on the transformation of solutions for the equations of gasdynamics into special sets according to parameter classes and is analogous to the transformation method for the solution of equations of motion of a viscous fluid in the boundary-layer theory.

NEKOTORYE OSOBENNOSTI OBTEKANIIA TEL PRI BOL'SHIKH SVERKHZVUKOVYKH SKOROSTIAKH. G. L. Grodzovskii. AN SSSR Otd. Tekh. Nauk Izv., June, 1957, pp. 86-92. 15 refs. In Russian. Determination of some flow characteristics simplifying considerably in the first approximation the study of flow around bodies for large Mach Numbers and providing an approach to a number of variational problems.

CONTRIBUTIONS TO THE THEORY OF THE PITOT-TUBE DISPLACEMENT EFFECT. M. J. Lighthill. J. Fluid Mech., July, 1957, pp. 493-512. 19 refs. Analysis of the downwash (secondary flow component perpendicular to the undisturbed flow in the lower velocity gradient) on the dividing streamline. Difficulties due to the infinite domain of integration and singularities of the

integrand are overcome by selecting variables of integration carefully and using known analytical properties of the secondary vorticity. Results show that secondary trailing vorticity is not an important contributer to the displacement. The downwash is due almost entirely to vorticity upstream of the sphere, and this in turn produces displacement principally through its image vorticity. The relation between theories for a sphere and experimental results on Pitot tubes is discussed.

DIE INSTATIONÄRE ZWEIDIMENSIONALE ÜBERSCHALLSTROMUNG UM EINE PLÖTZLICH ANGESTELLTE DÜNNE PLATTE. I. Ryhming. DVL Bericht No. 35, May, 1957. 22 pp. Westdeutscher Verlag, Köln & Opladen. In German. Calculation of the velocity distribution in a nonstationary two-dimensional wave produced by a sudden angle of attack of an infinitely long plate in supersonic flow.

REIHENENTWICKLUNG DES GESCHWINDIGKEITSPOTENTIALS DER LINEAREN UNTER- UND ÜBERSCHALLSTRÖMUNG FÜR KÖRPER NICHT MEHR KLEINER STRECKUNG. F. Keune. ZFW, Aug., 1957, pp. 243-247. In German. Derivation of formulas for the terms of the velocity potential of subsonic and supersonic flow over not-so-slender bodies at zero lift, and of the formulas for the errors with regard to the exact solution of the linear equation of continuity. The discussion includes as part of the general theory a particularly simple derivation of the theory for slender bodies.

ANALYSIS OF SHOCK MOTION IN DUCTS DURING DISTURBANCES IN DOWNSTREAM PRESSURE. H. G. Hurrell. US, NACA TN 4090, Sept., 1957. 11 pp. Inquiry into the effect of small downstream pressure disturbances on the position of a normal shock in a duct with area variation. The gas flow is treated as quasi-one-dimensional, and boundary layer is neglected. Results show a first-order lag relation between shock position and small downstream disturbances which occur at frequencies below a given limit. The time constant and the gain of this lag are expressed in terms of a dimensionless time constant that depends only on the steady-state Mach Number of the shock.

THEORY OF THE INTERACTION BETWEEN OBLIQUE SHOCK WAVES AND LAMINAR BOUNDARY LAYERS. M. Honda. Tôhoku U., Rep. Inst. High Speed Mech., vol. 8, 1957, pp. 109-130. 11 refs. Application of the usual boundary-layer assumptions to the inner viscous sublayer in Lighthill's theory. The change of the wall-pressure distribution with the increase of the shock strength is determined, as is the shock strength required to bring about the boundary-layer separation.

EXPERIMENTS ON INTERACTION BETWEEN A TRAVELING SHOCK WAVE AND A TURBULENT JET. D. S. Dosanjh. J. Aero. Sci., Nov., 1957, pp. 838-844. 21 refs. USAF-Navy sponsored optical observations using various arrangements of both sub- and supersonic jets. Some typical shadowgraphs are reproduced and discussed, including a sequence of instantaneous shadowgraphs through which the growth and behavior are recorded for a bulge developed in the shock wave as a direct result of the shock wave's passage through the jet. The transverse spread and the changing profile of this bulge provide a visual demonstration of the angle of spread and decay of the jet flow. It is shown that beyond an equivalent distance of about 12 jet diams. the bulge profile reaches a state of similarity. Includes some possible explanations of an intense, intermittent, high-frequency acoustic radiation manifested when the shock and the jet collide head-on.

AN ANALYSIS OF THE EFFECT OF SHOCK WAVES ON TURBULENT BOUNDARY LAYERS. A. G. Hammitt, I. E. Vas, and S. Hight. Princeton U. Dept. Aero. Eng. Rep. 396, July, 1957. 45 pp. 21 refs. Study of boundary-layer surveys in the region of the interaction between shock waves and turbulent boundary layers. By the analysis it is possible to determine the order of magnitude of the static pressure gradient across the boundary layer and changes of mass and momentum in the boundary layer. The results indicate that the static pressures across the boundary layer in the interaction region are far from constant, and that shear forces have only a secondary effect on the total momentum in the boundary layer.

THE ANALYSIS OF SIMPLE WAVE FLOW USING A SYSTEM OF CONSTANT ENTROPY SHOCK WAVES. Appendix I - CONDITIONS FOR A STATIONARY VALUE IN THE SHOCK SYSTEM ENTROPY. Appendix II - LIMITING VALUE OF THE SHOCK SYSTEM DEFLECTION EQUATION. Appendix III - EVALUATION OF THE INTEGRALS. Appendix IV - ERROR IN THE PITCHING MOMENT. L. F. Henderson. Australia, ARL Rep. Met. 84, June, 1957. 38 pp. Development of a two-dimensional theory in which the flow-field Mach lines are regarded as shock waves of small intensity. The theory is applied to a two-dimensional wing in order to permit comparison between calculated and measured pressure distributions.

THE VORTICITY JUMP ACROSS A GASDYNAMIC DISCONTINUITY. W. D. Hayes. J. Fluid Mech., Aug., 1957, pp. 595-600. Derivation of an expression for the jump in the vorticity across a gasdynamic discontinuity in an inviscid flow. The expression generalizes results of Truesdell and of Lighthill for the vorticity behind a steady curved shock in a uniform flow, as well as Emmons' result for the vorticity jump across a flame. The jump in vorticity considered in the steady-flow case in found to depend on the jump in density and on gradients along the discontinuity surface of the tangential velocity component and of the normal mass flow. An analogous result is found with unsteady flow.

DIFFRACTION OF DISTURBANCES AROUND A CONVEX RIGHT CORNER WITH APPLICATIONS IN ACOUSTICS AND WING-BODY INTERFERENCE. Lu Ting. J. Aero. Sci., Nov., 1957, pp. 821-844. 31 refs. OSR-supported analysis of the problem of diffraction of a two-dimensional disturbance or an

arbitrary pulse by a convex right-angled corner. The matching of the boundary conditions of the solutions to these two problems leads to a nonhomogeneous integral equation for the pressure distribution along the boundary. The solution of this is obtained by the method of successive substitution. Applications are made to the analysis of the two-dimensional unsteady flow field associated with the diffraction of a weak shock by a rectangular barrier and to the analysis of the equivalent three-dimensional steady supersonic flow field produced by interference of wings and prismatic bodies of rectangular cross section.

Internal Flow

AN EXPERIMENTAL INVESTIGATION OF THE SECONDARY FLOW OCCURING IN A COMPRESSOR CASCADE. W. D. Armstrong. Aero. Quart., Aug., 1957, pp. 240-256. Test results from a 6-in.-chord cascade giving velocity measurements and the three-dimensional tracks of air particles. The experimental and computed outlet angles are compared and the discrepancies are explained qualitatively. It is shown that secondary flow between two compressor blades causes a local separation of the suction surface boundary layer adjacent to the cascade wall. As a result the cascade wall boundary layer is appreciably thickened, and farther downstream the deflection of the flow over the concave surface is reduced. Local curvature of the streamlines near the nose also generates a stable secondary flow pattern, the vortices of which pass around the nose. On the convex blade surface the streamlines oppose the secondary vorticity, but are additive near the concave surface.

ANALYSE GENERALE DE L'ECOULEMENT SUBSONIQUE DANS UN COMPRESSEUR HELICO-CENTRIFUGE. M. Costedoat, J. le Manach, and E. Maillet. France, ONERA Pub. 86, Feb., 1957. 42 pp. In French. General analysis of subsonic flow in a helico-centrifugal compressor based on experimental determination of the evaluation and location of losses.

SCHWINGUNGEN IN VERDICHTERN. H. Söhngen and A. W. Quick. France, ONERA, J.I.S.A., Paris, May 27-29, 1957, Comptes Rendus, Pt. I, pp. 119-130. In German. Investigation emphasizing the importance of gas compressibility in the case of vibration of axial compressors and indicating its use in explaining numerous vibration phenomena. The validity of this theory is illustrated for the case of small stationary flow velocities and its inadequacy in the case of a grid with sufficiently large frequencies is pointed out. The compressibility of gases must also be taken into account when air forces are calculated for the nonstationary case.

ÜBER DEN KOMPRESSIBILITÄTSEINFLUSS BEI EBENEN SCHAUFELGITTERN STARKER UMLENKUNG. K. Oswatitsch and I. Ryhming. DVL Bericht No. 28, Mar., 1957. 29 pp. Westdeutscher Verlag, Köln & Opladen. In German. Study of the compressibility effect in the case of two-dimensional cascades with strong deflection, taking into account the Prandtl-Glauert analogy, and including the determination of the influence of blade curvature on the critical Mach Number of the oncoming flow.

INLET FLOW DISTORTION INDEX. J. S. Alford. France, ONERA, J.I.S.A., Paris, May 27-29, 1957, Comptes Rendus, Pt. I, pp. 71-94. Discussion of methods for improving the compatibility of inlet ducts and engines through adequate programing in these areas: (a) design of induction system for good flow distribution, (b) development of flow-distributing devices, (c) design of compressors to accept moderate distortion, and (d) matching of inlet-flow distribution to engine requirements. An inlet-flow distortion index is developed from the proposition that the effect of circumferential variations of total pressure on engine-stall margin is proportional to the magnitude of distortion and to the number of stages over which the distortion persists.

THE PRODUCTION OF UNIFORM SHEAR FLOW IN A WIND TUNNEL. P. R. Owen and H. K. Zienkiewicz. J. Fluid Mech., Aug., 1957, pp. 521-531. Method for calculating a suitable arrangement of parallel rods such that, when a grid of these rods is inserted with varying spacing in the working section of a wind tunnel, a nearly uniform shear flow is obtained. The function of the grid is to impose a resistance to the flow, so graded across the working section as to produce a linear variation in the total pressure at large distances downstream, without introducing an appreciable gradient in static pressure near the grid. Treatment includes experimental verification using a grid designed for a shear parameter as large as 0.45.

TRANSONIC FLOW WITH A DETACHED BOW WAVE PAST A WEDGE BETWEEN TWO PARALLEL PLANE WALLS. Shigeki Morioka. J. Aero. Sci., Nov., 1957, pp. 831-837. Calculations of the flow past a symmetrical double wedge placed midway between two parallel walls. The subsonic flow field over the front half is determined by applying the hodograph technique to the transonic perturbation equation in the hodograph plane. The method of characteristics is adopted for supersonic flow over the rear half. Computations are carried out for three values of the ratio of the chord length to the tunnel width, assuming the value of the transonic parameter to be 0.921 in every case.

STUDY OF THE CURVING OF THE FREE JET. Ajit Kumar Roy. Aero. Soc. India J., May, 1957, pp. 28-33. Analysis of three cases falling in the category of the Helmholtz problem of a free jet impinging on a solid boundary where mixed boundary conditions exist. These boundary conditions include prescribed velocity magnitude on the free streamline and constant velocity direction on the boundary. Considered are (a) the case in which the jet flow is within two parallel walls extending to infinity both ways, (b) the case of an outgoing widened jet which is turned 90° away from the incoming jet with the help of boundaries, and (c) an

extension of case (b) in which the perpendicular boundaries are moved an infinite distance apart and the motion takes place such that the free streamline makes an unlimited number of turns in the form of a spiral.

ON THE TILTING OF NOZZLE LINERS. T. A. d'Ews Thomson and R. E. Meyer. Australia, ARL Rep. A. 100, Jan., 1957. 26 pp. Analytical determination of the effect of a slight tilting on the Mach Number distribution in the test rhombus. Meyer's perturbation theory for supersonic nozzle flows serves as the basis for the investigation. It is shown that the sub- and transonic perturbations of the flow may be neglected as compared with the supersonic perturbations. This result is confirmed by experimental data which indicate further, however, that appreciable effects not accounted for by the theory in its present form occur when the flow possesses high local pressure gradients.

THE LAMINAR AND TURBULENT MIXING OF JETS OF COMPRESSIBLE FLUID. I - FLOW FAR FROM THE ORIFICE. L. J. Crane and D. C. Pack. J. Fluid Mech., July, 1957, pp. 449-455. Analysis based on the assumption of a coefficient of eddy kinematic viscosity in turbulent flow, leading to the possibility of combining, in one equation, laminar and turbulent motion. An approximation to the solution of these equations is found for the flow of a compressible fluid, issuing from a narrow slit, far from the slit. The stream function is expanded in a power series in squares of the Mach Number. Bickley's solution for the corresponding problem in compressible flow is used to start the iterative process by which successive terms of the power series are obtained. In order to find the analytical form for the second term of the series, it is assumed that the Prandtl Number is unity, that the viscosity varies as the n-th power of the absolute temperature, and that the stagnation temperature of the jet is the same as that of the surrounding gas.

AN EXPERIMENTAL INVESTIGATION OF A WALL JET. P. Bakke. J. Fluid Mech., July, 1957, pp. 467-472. Study of a turbulent low-speed jet of air spreading radially over a flat smooth plate, a situation discussed by Glauert in his theory of the wall jet. The velocity distribution is measured and is found to agree with Glauert's theory within experimental range and accuracy. The rate of change of velocity and the width of the jet can be expressed by simple power laws.

Stability & Control

STATIC LONGITUDINAL AND LATERAL STABILITY CHARACTERISTICS AT LOW SPEED OF 45° SWEPTBACK-MIDWING MODELS HAVING WINGS WITH AN ASPECT RATIO OF 2, 4, OR 6. D. F. Thomas, Jr., and W. D. Wolhart. US, NACA TN 4077, Sept., 1957. 30 pp. 15 refs. Systematic stability-tunnel investigation of the effects of the various components and component combinations on the considered static longitudinal and lateral stability characteristics. Results indicate that the wing-on tail effectiveness in producing negative pitching moment increases with aspect ratio and angle of attack, and becomes approximately equal to the wing-off value at very high angles of attack. It is also shown that the complete models tested become directionally unstable in the high angle-of-attack range, primarily as a result of increased losses in the stable contribution of the tail both with angle of attack and with increasing wing aspect ratio.

A NOTE ON THE EQUATIONS OF MOTION FOR A RIGID AIRCRAFT WITH VARYING MASS. Kyuichiro Washizu. Japan Soc. Aero. Eng. J., Aug., 1957, pp. 215-218. In Japanese. Derivation of equations of motion for a rigid aircraft propelled by a cigarette-burning type of rocket propellant, taking into account effects of varying mass and a moving center of gravity position. In this method, an aircraft coordinate system is fixed at a rigid point of the aircraft. Therefore, the magnitudes of aerodynamic forces and moments with respect to the axis of the aircraft coordinate depend on motions of the aircraft only, and not on the instantaneous position of its center of gravity.

A METHOD UTILIZING DATA ON THE SPIRAL, ROLL-SUBSIDENCE, AND DUTCH ROLL MODES FOR DETERMINING LATERAL STABILITY DERIVATIVES FROM FLIGHT MEASUREMENTS. B. B. Klawans and J. A. White. US, NACA TN 4066, Aug., 1957. 38 pp. Analysis using the lateral equations of motion arranged in such form that information from each of the three modes of lateral motion may be utilized. This permits the determination of all the important derivatives without requiring an estimation of any of the derivatives. The results of an error analysis are given to show the effect of errors in the measured quantities on the accuracy of each stability derivative for three representative airplanes.

Wings & Airfoils

THE HILBERT PROBLEM FOR AN AIRFOIL IN UNSTEADY FLOW. Patrick Leehey. J. Math. & Mech., July, 1957, pp. 427-453. 13 refs. Application of Kelvin's circulation theorem and of certain results concerning the interchange of integration processes for contours and arcs, to relate the wake vortex distribution to a prescribed vertical motions of the airfoil. General lift and pitching-moment expressions are obtained and applied to special cases of (1) a step change in angle of attack, (2) a translatory oscillation, (3) an airfoil in an oscillating, moving stream.

THE SHAPE OF THE CENTRE PART OF A SWEPTBACK WING WITH A REQUIRED LOAD DISTRIBUTION. J. Weber. Gt. Brit., RAE Rep. Aero. 2591, May, 1957. 51 pp. Development of a method for designing the center portion of a cambered and twisted sweptback wing to have the same chordwise load distribution at all spanwise locations. For this purpose the downwash field induced by a doublet distribution of constant spanwise strength in the chordal plane of a constant chord wing is determined for incompressible, sonic, and

supersonic mainstream flow. Since the downwash has a logarithmic singularity at the center section in the chordal plane itself, an approximate method is suggested to satisfy the boundary condition at the surface of the thick wing. Numerical examples illustrate the influence of the angle of sweep, the wing thickness, and the load distribution.

EXPERIMENTELLE UNTERSUCHUNGEN AN NEUEN LAMINARPROFILEN FÜR SEGELFLUGZEUGE UND HUBSCHRAUBER. F. X. Wortmann. ZFW, Aug., 1957, pp. 228-243. 18 refs. In German. Development, based on theoretical concepts, of new laminar airfoil sections, and tests on these sections and on two NACA airfoil sections in a low-turbulence wind tunnel at Reynolds Numbers between 0.7×10^6 and 1.8×10^6. The theoretical concepts are completed and corrected. Over the same low-drag range, the airfoil sections of the final design show a drag reduction of 15 to 20% or, for the same drag, a 25% increase of the low-drag range when compared with the corresponding NACA airfoil sections.

A NOTE ON THE APPLICATION OF THE SUPERSONIC AREA RULE TO THE DETERMINATION OF THE WAVE DRAG OF RECTANGULAR WINGS. R. C. Lock. J. Fluid Mech., Aug., 1957, pp. 575-582. Presentation of a proof that, despite certain singularities in the oblique area distributions, the supersonic area rule can be used to determine correctly the wave drag according to linearized theory, of thin symmetrical rectangular wings at zero incidence. It is shown that the proof can be extended to cover the case of swept wings with supersonic edges, for which similar singularities also exist.

INVESTIGATIONS ON THE STALLING CHARACTERISTICS OF DELTA WINGS IN INCOMPRESSIBLE FLOW. E. Truckenbrodt and E. G. Feindt. Braunschweig Tech. Hochschule Inst. Strömungsmech., Rep. 57/11a, June 4, 1957. 46 pp. Evaluation of four delta wings having NACA 0012 wing sections but differing in aspect ratios, and of one having an NACA 0005 wing section. The critical angle of incidence at which separation begins is determined from wake measurements, according to a method due to Hofer. Separation begins at higher angles of incidence for wings with small aspect ratios than for those with large aspect ratios. The plan forms with 12%-thick profiles have less tendency for separation than those with 5%-thick profiles. For all plan forms investigated, separation starts at the wing tip and, with increasing angle of incidence, proceeds to the root. The results of the measurements of the critical angle of incidence are compared with data from pressure-distribution measurements.

SLENDER DELTA WINGS WITH SHARP EDGES AT ZERO LIFT. J. Weber. Gt. Brit. RAE TN Aero. 2508, May, 1957. 45 pp. 27 refs. Investigation of delta wing with diamond-shaped cross sections at subsonic and at supersonic speeds. The pressure distributions and overall normal-pressure drags resulting from various theoretical methods are compared with one another. Includes discussion concerning the possibility of achieving the results, calculated for an inviscid stream, in a real flow, in the presence of a viscous layer around the body.

THEORY OF THE CIRCULAR WING IN STEADY INCOMPRESSIBLE FLOW. E. van Spiegel. Netherlands, NLL TN F.189, Jan. 25, 1957. 57 pp. Analysis of circular planform with any downwash distribution in an incompressible flow, formulated as a boundary-value problem for the Laplace equation. Orthogonal coordinates are introduced, and solutions are found by separation of variables. By means of these solutions the Green's function of the second kind can be constructed. A comparison of the regular velocity potential and the regular acceleration potential leads to singular solutions of the Laplace equation. The complete solution of the physical problem can be written as the sum of the regular acceleration potential and a singular solution along the leading edge of the wing.

EXPERIMENTAL OBSERVATION OF VORTICES IN WING-BODY JUNCTIONS. A. Stanbrook. Gt. Brit., RAE Rep. Aero. 2589, Mar., 1957. 33 pp. 13 refs. Tests on various wing-body combinations to investigate the nature of the flow in the junction. Results indicate that vortices are formed due to separation of the boundary layer on the body in the flow towards the wing. The free edge of the resulting vortex sheet rolls up to form a vortex which then trails downstream around the wing. As incidence is increased, the vortex on the suction side of the wing moves toward the wing and the vortex on the pressure side moves away from the wing. The vortices are present with both swept and unswept rounded leading edges at sub- and supersonic speeds; they are not found, however, with sharp leading edges at zero incidence.

AEROELASTICITY

APPLICATION OF DONNELL-TYPE DYNAMIC EQUATIONS INCLUDING AND EXCLUDING THE EFFECTS OF TRANSVERSE SHEAR AND ROTATIONAL INERTIA TO VIBRATIONS OF INFINITELY LONG CYLINDRICAL SHELLS. Yi-Yan Yu. Syracuse U., Res. Inst. Mech. Eng. Dept. Rep. ME390-577TN2 (AFOSR TN 57-390) [AD 132465], July, 1957. 56 pp. Analysis to present Donnell-type dynamic equations in a form such that the terms affected by rotational inertia as well as those affected by transverse shear deformation may be identified. The equations are then reduced to their exact counterpart, in which transverse shear and rotational inertia effects are neglected. By means of the two counterpart equations, expressions are then derived for the frequency, modes, phase, and group velocities of long cylindrical shells.

THE USE OF NORMAL MODES IN PROBLEMS OF FORCED VIBRATION AND IMPACT. R. P. N. Jones. RAeS J., Aug., 1957, pp. 552-559. 10 refs. Derivation of the properties of modes by use of d'Alembert's principle and methods of virtual work. The solutions of problems of free and forced vibrations, and of dynamic loading, are discussed in

conjunction with simple examples. It is shown that dynamic problems for any linear system may be solved without the use of the fundamental equations of motion, provided the natural frequencies and modes of the system are known. In most problems the solutions converge rapidly, so that only the first few modes of vibration need be considered, and in these cases the solution may be modified to give further improvement in convergence.

THE OSCILLATING TWO-DIMENSIONAL AEROFOIL BETWEEN POROUS WALLS. D. G. Drake. Aero. Quart., Aug., 1957, pp. 226-239. Application of the transform technique to the analysis of compressible flow past an oscillating two-dimensional airfoil in a wind tunnel with porous walls. The porous wall is assumed to have the property of constant ratio of the normal velocity at the wall to the pressure drop across the wall. The supersonic longitudinal stability derivatives are found, and an extension of Possio's integral equation is made for the quasi-stationary case in subsonic flow.

ON STABILITY CRITERIA FOR FLUTTERING SYSTEMS. Appendix I - EXPLICIT STABILITY CRITERIA FOR SIMPLER SYSTEMS. Appendix II - AN EXAMPLE OF STABILITY ANALYSIS OF TERNARY FLUTTER. J. D. C. Crisp. Australia, ARL Rep. SM 250, Apr., 1957. 34 pp. Generalization and formalization, for the specifically fluttering system, of the application of the Cauchy "residue theorem" to the study of the roots of the complex polynomial equation (with constant coefficients defined by the physical parameters of the system), to which the characteristic equation for nontrivial solutions of the equations of motion of an n-degree-of-freedom fluttering system reduces. A simplified, concise statement of the resulting graphical criterion is suggested which may be useful for second-, third-, and fourth-order systems in flutter design and system parametric studies.

ON THE EXCITATION OF PURE NATURAL MODES IN AIRCRAFT RESONANCE TESTING. R. W. Traill-Nash. Australia, ARL Rep. SM. 254, July, 1957. 12 pp. Presentation of a method for the systematic adjustment of force levels to produce a pure, undamped, natural mode of vibration in multipoint excitation of aircraft structures. The method requires the recording, initially, of in-phase components of displacement at a number of points on the structure for each of a number of linearly independent force distributions applied at the undamped natural frequency of the mode to be measured. From these data, a set of linear simultaneous equations is set up, the solution of which provides the coefficients of a linear combination of the force distributions which will serve to excite the pure mode. As part of the present study, the question of the optimum numbers of measuring stations and exciters is examined.

A CORRELATION OF RESULTS OF A FLIGHT INVESTIGATION WITH RESULTS OF AN ANALYTICAL STUDY OF EFFECTS OF WING FLEXIBILITY OF WING STRAINS DUE TO GUSTS. Appendix - DERIVATION OF THE FREQUENCY-RESPONSE FUNCTIONS INCLUDING VERTICAL MOTION AND FIRST AND SECOND SYMMETRICAL MODES OF WING BENDING. C. C. Shufflebarger, C. B. Payne, and G. L. Cahen. US, NACA TN 4071, Aug., 1957. 40 pp. 14 refs. Application of the techniques of generalized harmonic analysis in both the theoretical calculations and in the analysis of the wing-strain measurements previously made on a four-engine bomber airplane during flight through rough air. Strain spectra, root-mean-square strain values, and the distribution of strain peaks are determined for each of the four spanwise measuring stations. Horbolt and Kordes' method is extended to include the second symmetrical bending mode, in addition to the fundamental bending mode, as it seems particularly pertinent for the outboard stations.

AIRPLANE DESIGN

THE ROLE OF DYNAMIC TECHNIQUES IN THE DESIGN AND DEVELOPMENT OF HIGH SPEED AIRCRAFT. R. R. Heppe. France, ONERA, J. I.S.A., Paris, May 27-29, 1957, Comptes Rendus, Pt. I, pp. 1-25. Discussion of various techniques including the use of high-speed computers, dynamic analysis, and certain experimental procedures. One new flight-dynamic experimental technique is described. Typical results of the application of modern analytical methods are shown in the areas of flying characteristics, aeroelasticity, loads, automatic controls, and aircraft performance.

AIRPORTS

Heliports

INVESTIGATION OF AIR TURBULENCE ON HELIPORTS. W. Just. AHS J., July, 1957, pp. 19-26. Experimental investigation of the flow conditions on a rooftop heliport. Includes flow pictures taken in a water channel, and study of the influence of rounding the roof edges and of the effect of attached slats and corner fairings. Results indicate that rounded roof edges and a slat or forward-edge fairings aid in minimizing turbulence. The disturbance caused by buildings standing in the vicinity of rooftop landing areas is also illustrated.

FUELS & LUBRICANTS

SPECIAL ISSUE: ROCKET PROPELLANTS. (CCDA Spring Meeting, French Lick, Ind., May 13-14, 1957.) Ind. & Eng. Chem., Sept., 1957, pp. 1,330-1,348. Partial contents: FLUORINE-DERIVED CHEMICALS AS LIQUID PROPELLANTS, J. F. Gall. APPLIED RESEARCH AND PRODUCT DEVELOPMENT FOR ROCKET PROPELLANTS, A. R. Deschere. UTILIZATION OF HIGH-ENERGY FUEL ELEMENTS, E. A. Weilmuenster. LIQUID ROCKET PROPELLANTS - IS THERE AN ENERGY LIMIT, J. F. Tormey. HOMOGENEOUS SOLID PROPELLANTS AND THE CHEMICAL INDUSTRY, L. G. Bonner. CHEMICAL LESSONS LEARNED FROM NIKE AJAX DEVELOPMENT, R. B. Canright. THE CHEMICAL INDUSTRY IN MISSILE SYSTEMS PLANNING, S. A. Johnston and H.

R. Lawrence. Symposium which discusses new high-energy fuels using boron and fluorine chemicals, in addition to research and production problems.

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POWER PLANTS

Jet & Turbine

INTERACTION DE L'ECOULEMENT EXTERNE ET DE L'ECOULEMENT INTERNE A LA SORTIE D'UN REACTEUR, AUX VITESSES TRANSSONIQUES ET SUPERSONIQUES. P. Carrière. France, ONERA, J.I.S.A., Paris, May 27-29, 1957, Comptes Rendus, Pt. I, pp. 43-69. 17 refs. In French. Analysis of the importance of interaction effects and presentation of some examples pertaining to the real thrust variations of a nozzle as related to the theoretical maximum thrust in the case of varying external and internal flow conditions. By visualizing the flow, different aspects of the interaction phenomena can be emphasized, e.g., separation along the wall or downstream of the throat, followed by reattachment of the two flows. Also presented is an analysis of the interaction phenomena, including the problem of boundary-layer separation produced by a rapid pressure increase, the influence of the laminar or turbulent state of the boundary layer, mathematical difficulties arising, and some simple results obtained from Navier-Stokes equations.

APPROXIMATION FOR THE EFFECT OF TWIST ON THE VIBRATION OF A TURBINE BLADE. Appendix I - EXACT FORM OF THE FREQUENCY EQUATION. Appendix II - SOME FURTHER INTEGRALS RELATING TO THE VIBRATION OF A CANTILEVER BEAM. Appendix III - THE CASE WHEN r APPROACHES UNITY. VIBRATION OF A SLIGHTLY TWISTED SQUARE PRISM. A. I. Martin. Aero. Quart., Aug., 1957, pp. 291-308. 12 refs. Application of the Clebsch-Kirchhoff theory for rods which are naturally twisted, to derive equations for the flexural vibrations. The equations may be solved approximately by treating the twist as a first order perturbation. It is shown that, for a given overtone or harmonic, K (a function of the shape of the cross section) depends only on the ratio r of the two principal moments of inertia of the cross section. Values of K are tabulated for first, second, third, and fourth overtones.

INLET-ENGINE MATCHING AND CONTROL SYSTEMS FOR SUPERSONIC AIRPLANES. C. F. Schueller. France, ONERA, J.I.S.A., Paris, May 27-29, 1957, Comptes Rendus, Pt. I, pp. 27-41. 12 refs. Discussion of the complications in inlet design associated with operation at higher Mach Numbers and illustration of some possible techniques for matching a supersonic inlet to a hypothetical turbojet engine. For air-breathing power plants required to operate over a speed range up to Mach Number 4 it is concluded that (a) proper inlet-engine matching, corresponding to nearly optimum thrust minus drag performance, requires the use of some type of variable-geometry inlet; (b) critical operation of the inlet at less than the design speed will probably result in much more airflow than a turbojet engine requires; and (c) closed-loop inlet-control systems can be designed to assure inlet operation at near optimum conditions, either by sensing the normal shock location or by sensing the diffuser Mach Number.

Rocket

DEMONSTRATING SYSTEM RELIABILITY BY THE SEQUENTIAL PROBABILITY RATIO TEST. Bernard Tiger, and W. H. Brewington. (ARS 11th Annual Meeting, New York, Nov. 26-29, 1956.) Jet Propulsion, Aug., 1957, pp. 890, 891. Presentation of the test as a practical statistical approach for rocket systems and subsystems. Rather than predetermination of the sample size, the procedure involves continuation of testing and analysis of results after each system is tested, until the results are sufficient to indicate a decision. Advantages cited include (a) a generally smaller sample size that that required by other statistical procedures and (b) all calculations can be done prior to testing and the test data can be recorded graphically without additional computations.

EFFECT OF FLUID-SYSTEM PARAMETERS ON STARTING FLOW IN A LIQUID ROCKET. Appendix A, B - PUMP EQUATIONS. Appendix C - DIFFERENTIAL EQUATIONS OF MOTION. R. P. Krebs. US, NACA TN 4034. Sept., 1957. 38 pp. Analysis to determine the influence of configuration parameters and valve area-time operating relations on the speed of response of the liquid flow and the suppressed suction head of the pump in a rocket motor. The configuration considered consists of tank, pump, combustion chamber, valves, and lines, including a bypass line with a valve around the pump. Results indicate that, for a given change in volume flow and given valve operating time, the maximum suppression head is minimized by a flow increase which is linear with time. The maximum suppression head varies directly with the length of the suction line to the pump, and inversely with the area of the line and the operating time of the main flow valve.

INVESTIGATION OF THE FACTORS AFFECTING THE ATTACHMENT OF A LIQUID FILM TO A SOLID SURFACE. C. F. Warner and B. A. Reese. (ARS Fall Meeting, Buffalo, Sept. 24-26, 1956.) Jet Propulsion, Aug., 1957, pp. 877-881. 15 refs. ONR-sponsored experimental investigation of the effects of liquid-injection velocity, gas velocity, slot geometry, liquid physical properties, and gas density on the film attachment when a protective liquid film is injected through a slot in the walls of a flow passage. A correlating equation is presented which is based upon momentum exchange for the case of radial injection.

ROTATING WING AIRCRAFT

INDEPENDENCE OF HELICOPTER ROTOR DERIVATIVES UNDER NON-UNIFORMITY OF

INDUCED VELOCITY DISTRIBUTION AT LOW FORWARD SPEED. W. W. Bryce. Coll. of Aeronautics, Cranfield, Rep. 110, Nov., 1956. 48 pp. 13 refs. Analysis of the effect of nonuniform induced velocity at low forward speeds using a parabolic radial distribution which agrees well with the flight made by Brotherhood. To this has been added a second induced velocity distribution, varying linearly from the front to the rear of the rotor disc, to allow for the effect of forward speed. The magnitude of this second induced velocity term depends on the advance ratio μ. Values of force coefficients, flapping coefficients, and rotor derivatives are calculated for the low forward speed region with both uniform an nonuniform induced velocity.

PROBLEMS ASSOCIATED WITH THE STRENGTH ASSESSMENT OF ROTOR BLADES. V. A. B. Rogers. Helicopter Assn. Gt. Brit. J., Aug., 1957, pp. 189-222; Discussion, pp. 222-236. Analysis of the different dynamical conditions associated with a complete ground-to-air flight cycle. The ground resonance is shown to be only a particular case of the lag-plane forced-oscillation problem. The calculation of the aerodynamic forced loading, used in conjunction with the dynamic equations, is discussed. An estimate of the modification necessary to bring calculated blade stress levels into line with those measured on the actual aircraft is given. It is concluded that a theoretical strength assessment is all right for design work, but it is necessary to verify the results thus obtained by adequate flight and structural testing in order to produce a safe aircraft.

SPACE TRAVEL

ORBITAL BEHAVIOR OF EARTH SATELLITES. I. R. E. Roberson. Franklin Inst. J., Sept., 1957, pp. 181-202. 13 refs. Analysis on the effect of the oblateness of the earth on the orbits of close satellites. Includes a review of recent work in this field and a discussion of some of the perturbation sources on a satellite orbit. A solution of the first order in the oblateness is developed by a method similar to Hansen's classical perturbation method for orbits about an oblate spheroid. Particular attention is given to the effect of initial conditions on the orbit elements.

STRUCTURES

A SIMPLE METHOD OF MATRIC STRUCTURAL ANALYSIS. II - EFFECTS OF TAPER AND CONSIDERATION OF CURVATURE. Bertram Klein. J. Aero. Sci., Nov., 1957, pp. 813-820. Extension of the previously presented matric method to include the effects of panel geometry and gage taper, stringer taper, and consideration of curved elements. Several problems are given to illustrate the mechanics and simplicity of the extended method, which permits the necessary final equations of equilibrium and compatibility to be written down directly and rapidly - once a structure is idealized - in final matrix form, without recourse to any artificial devices. The method makes it possible to obtain a complete solution to a problem, when such is required, and it allows for the direct treatment of cases involving thermal loadings and combined thermal and regular loadings.

THE DETERMINATION OF A FACTOR OF SAFETY ON THE BASIS OF A SINGLE PROBABILITY PARAMETER. J. Kloos and F. Turner. SAAB TN 37, 1957. 13 pp. Presentation of a procedure which permits application of Chilver's method for calculating in-service failure probability when maximum load in service is not fixed but is given by a probability distribution, compiled for the occurrence of high loads.

HANDBOOK OF STRUCTURAL STABILITY. I - BUCKLING OF FLAT PLATES. II - BUCKLING OF COMPOSITE ELEMENTS. III - BUCKLING OF CURVED PLATES AND SHELLS. George Gerard and Herbert Becker. US, NACA TN 3781, July-Aug., 1957. 102, 72, 154 pp. 184 refs. Critical review of various factors governing (a) the buckling of flat plates, (b) plates with sturdy stiffeners, and (c) the local buckling of stiffener sections, and review of available theories and test data on curved plates and shells. Results for (a), (b), and (c) are summarized in a comprehensive series of charts and tables, and numerical values are presented in some cases. Test data on torsion and external pressure for curved plates and shells are correlated for both the elastic and inelastic ranges, and a unified semi-empirical approach is used to analyze those cases for which analytical and experimental results are in marked disagreement.

DETERMINATION OF CRIPPLING STRESSES FOR CURVED FRAMES OF ALCLAD 24S-T IN BENDING. Gunnar Anevi. SAAB TN 36, 1957. 73 pp. Experimental investigation to create a basis for deciding the dimensions of curved frames of 24S-T aluminum. One-hundred-fifty-six tests are performed on specimens designed to the dimensions and manufacturing method most frequently used at Saab. The testing method simulates as well as possible the actual loading conditions. The crippling stresses obtained are considerably higher for bending moments giving compression in the outer flange than for those giving compression in the inner flange. Results also indicate that the radius of curvature for the frame has a relatively large effect on the crippling stress. A method for obtaining allowable crippling-stress values by means of a relatively simple formula is proposed. Results are analyzed with regard to weight efficiency.

Beams & Columns

EFFECT OF HIGHER-HARMONIC DEFLECTION COMPONENTS ON THE CREEP BUCKLING OF COLUMNS. S. A. Patel and J. Kempner. Aero. Quart., Aug., 1957, pp. 215-225. 10 refs. Analysis which shows that the higher-harmonic deflection components reduce the column lifetime significantly only when their initial amplitudes, as well as the initial amplitude of the first harmonic component, are very large. Furthermore, it is shown that second-harmonic components have a much

smaller effect on the column behavior than do third-harmonic components.

BUCKLING BEHAVIOUR OF THE COMPRESSION FLANGE OF A WIDE-FLANGED BEAM. S. Krishnan and S. G. Tewar. (Aero. Soc. India, 9th Annual Gen. Meeting, New Delhi, Feb. 23, 1957.) Aero. Soc. India J., May, 1957, pp. 15-27. Analytical determination of the buckling stress for the compression flange of a wide-flanged beam subjected to uniformly distributed load. A solution for the stress distribution is assumed, and a double series function is postulated to represent the deflected surface of the flange plate. The strain energy of the bent plate is equated to work done and a minimum value of the buckling normal stress is obtained by minimizing the strain energy with respect to the series coefficients. Values of buckling stress are computed, and curves are drawn showing the variation of the maximum shear that causes buckling and the corresponding maximium normal stress in flange. For a given length of beam, the buckling normal stress is plotted against the length/width ratio.

Cylinders & Shells

ON THE DONNELL EQUATIONS AND DONNELL-TYPE EQUATIONS OF THIN CYLINDRICAL SHELLS. Yi-Yuan Yu. Syracuse U., Res. Inst., Mech. Eng. Dept. Rep. ME390-578TN3 (AFOSR TN 57-464) [AD 136455], Aug., 1957. 21 pp. 19 refs. Review of previous work on Donnell equations of thin cylindrical shells, both static and dynamic. A complete set of Donnell-type dynamic equations, including the shear and rotation effects, is derived, which is shown to be reducible to the previous results. In particular, from this set of Donnell-type equations a set of Donnell dynamic equations is deduced which also includes the shear and rotation effects.

Elasticity & Plasticity

PRACTICAL SOLUTION ON PLASTIC DEFORMATION PROBLEMS IN ELASTIC-PLASTIC RANGE Appendix A, B - CALCULATION OF PLASTIC STRAINS. Appendix C - EQUATIONS FOR THIN SHELL. Appendix D - PLASTIC STRAIN CHARTS. Appendix E - LONG SOLID CYLINDER. Appendix F - ROTATING DISK. A. Mendelson and S. S. Manson. US, NACA TN 4088, Sept., 1957. 52 pp. Presentation of a method of successive approximations which is illustrated by four examples: a flat plate with temperature distribution across the width, a thin shell with axial temperature distribution, a solid cylinder with radial temperature distribution, and a rotating disc with radial temperature distribution.

A GENERAL THEORY OF PIECEWISE LINEAR PLASTICITY BASED ON MAXIMUM SHEAR. P. G. Hodge, Jr. J. Mech. & Phys. Solids, No. 4, 1957, pp. 242-260. 21 refs. ONR-sponsored development of a theory of plasticity for an initially isotropic material which satisfies the maximum shear stress initial yield condition. It is shown that the most general piecewise linear theory depends upon the initial yield stress, the rate of hardening, and three constants which describe the effect of hardening upon the condition for further yielding. Consideration is also given to a restricted type of problem in which all stress points continue to load on each face with which they come in contact. For such a problem the flow law can be explicitly integrated. Further, the classical principles of minimum potential and complementary energy are shown to be valid for this integrated law. The analysis is carried out in three-dimensional terms, and the case of plane stress is also considered.

ON UNIQUENESS AND STABILITY IN THE THEORY OF FINITE ELASTIC STRAIN. R. Hill. J. Mech. & Phys. Solids, No. 4, 1957, pp. 229-241. 16 refs. Establishment of a criterion for deciding when a solution is or is not unique. This criterion is further shown to be closely related to the condition that a state of finite strain should be stable under dead loading. These related conditions are obtained in a simple form by appropriate choice of stress and strain variables. Analytical results indicate the existence of a suggestive connection between the structure of the criteria and the idea of functional convexity in relation to the strain-energy density; this concept is explained in detail. Finally, the stability limit is characterized by eigenfunctions, or adjacent positions of equilibrium.

ON THE PROBLEM OF UNIQUENESS IN THE THEORY OF A RIGID-PLASTIC SOLID. IV. R. Hill. J. Mech. & Phys. Solids, No. 4, 1957, pp. 302-307. Characterization, by an extremum property in the set of virtual modes, of a sufficient condition previously obtained, in terms of the work-hardening rate, for the deformation mode in a properly formulated boundary-value problem.

THE EFFECTS OF INELASTIC ACTION ON THE RESISTANCE TO VARIOUS TYPES OF LOADS OF DUCTILE MEMBERS MADE FROM VARIOUS CLASSES OF METALS. IV - ECCENTRICALLY-LOADED COLUMNS HAVING ANGLE- AND T-SECTIONS, M. E. Clark and O. M. Sidebottom. V - INELASTIC BEHAVIOR OF ALUMINUM ALLOY I-BEAMS WITH ELLIPTICAL WEB SECTION CUTOUTS, W. J. Worley. VI - A DIGITAL COMPUTER ANALYSIS OF BENDING MOMENT-AXIAL LOAD INTERACTION CURVES, Y. Maeda, P. Van Lierde, O. M. Sidebottom, and M. E. Clark. USAF WADC TR 56-330, Pts. IV, V, VI [AD 130765; 130768; 118300], May, 1957. 31, 26, 34 pp. IV - Theoretical and experimental investigation to determine the load necessary to produce any given depth of yielding in angle- and T-section columns subjected to eccentric loads. V - Extension of previous study on aluminum I-beam with elliptical web cutouts to investigate plastic bending behavior, and application of the upper bound theorem to predict the ultimate loads of the various beams. VI - Study using a strip method of integration to solve equations of equilibrium for the members.

Plates

STRESS DISTRIBUTION IN A RECTANGULAR PLATE UNDER A PAIR OF CONCENTRATED FORCES. N. Yamaki. Tôhoku U., Rep. Inst. High Speed Mech., vol. 8, 1957, pp. 1-12. Theoretical determination of the stress state in a rectangular plate under a pair of concentrated forces and calculation of the stress distribution along the two central axes for rectangular plates with various values of the aspect ratio. The results are compared with the experimental data obtained by the photoelastic method and by the resistance strain-gage method, and the validity of the solution is ascertained.

PLASTIC BENDING OF AN ANNULAR PLATE. P. G. Hodge, Jr. J. Math. & Phys., July, 1957, pp. 130-137. 12 refs. Solution for an infinite annular plate simply supported at the inner edge and subjected there to a prescribed moment. The material of the plate is rigid-plastic, satisfies Tresca's yield condition and associated plan rule, and hardens according to a linear isotropic law. The key to the solution is that the complete stress and strain solution in each portion of the plate depends only upon conditions outboard of that region. Therefore, as each new region is formed at the edge of the hole, appropriate initial conditions are immediately available for integrating the flow laws.

SPANNUNGSFELD DER AUF DEN RAND EINER ELASTISCH ANISOTROPEN HALBEBENE WIRKENDEN TANGENTIALKRAFT. H. H. Stadelmaier. ZAMP, July 25, 1957, pp. 285-290. In German. Presentation of a closed-form solution for the stress distribution obtained by solving the two-dimensional problem in an anisotropic medium with boundary conditions of a concentrated tangential load acting on the boundary of a semi-infinite plate. The solution is shown to be purely radial and is combined with the solution for a concentrated normal load in order to solve the problem of an inclined force acting on the boundary.

BUCKLING OF A CIRCULAR PLATE UNDER LOCALLY DISTRIBUTED FORCES. N. Yamaki. Tôhoku U., Rep. Inst. High Speed Mech., vol. 8, 1957, pp. 13-24. Approximate solution for the problem of the elastic instability of a thin circular plate subjected to a pair of locally distributed forces applied on the edge. The Ritz method is used and the problem is solved for two cases - one in which the edge is clamped, and one in which it is simply supported. In each case, buckling loads and deflection surfaces for various values of the load width are calculated and the results are graphed and discussed.

PLASTIC BENDING OF A RING SECTOR BY END COUPLES. W. M. Shepherd and F. A. Gaydon. J. Mech. & Phys. Solids, No. 4, 1957, pp. 296-301. Application of Hill's maximum work principle to the problem of the incipient plastic flow in plane stress in a uniform, isotropic, thin, plane plate of plastic-rigid material in the shape of a ring sector, when the curved edges are free and the plate is in equilibrium under the action of couples applied, in the plane of the plate, to the straight edges. Both the Mises and Tresca yield criteria and their associated flow rules are used.

PURE BENDING OF PRETWISTED RECTANGULAR PLATES. L. Maunder and E. Reissner. J. Mech. & Phys. Solids, No. 4, 1957, pp. 261-266. Derivation of an explicit solution which is a generalization of known simple solutions for plane stress and for transverse bending of flat plates. It is suggested that the results may have application to turbine and compressor blades, and to aircraft propellers.

Thermal Stress

THE STATE OF STRESS IN AN ELASTIC SEMI-SPACE DUE TO AN INSTANTANEOUS SOURCE OF HEAT. W. Nowacki. Acad. Pol. Sci. Bul., Aug., 1957, pp. 165-173. Solutions obtained by determining the Green function for the problem of heat sources constituting continuous functions of time and distributed over the region T of the plane z = 0. Since, in the case of continuous time, the state of stress can be treated as quasi-static, it is assumed that the inertia terms of the theory of elasticity can be disregarded. It is also assumed that the z = 0 phase is thermally insulated, and that the temperature distribution over the plane is zero except for the point where the heat source is located.

A QUASI-STATIONARY THERMO-ELASTIC PROBLEM IN THREE DIMENSIONS. W. Nowacki. Acad. Pol. Sci. Bul., No. 3, 1957, pp. 155-163. Analysis to determine the displacement and stress which occur in an elastic semi-space due to the action of a source of heat (of intensity W) moving with a constant velocity v in the plane bounding the semi-space. The material is assumed to be thermally and elastically isotropic, and the values characterizing the material are assumed to be constant and independent of the temperature and stress. The stress solution is represented by Fourier integrals along with a function ϕ, the so-called potential of thermoelastic displacement.

THE STATE OF STRESS IN AN ELASTIC SPACE DUE TO A SOURCE OF HEAT VARYING HARMONICALLY IN FUNCTION OF TIME. W. Nowacki. Acad. Pol. Sci. Bul., No. 3, 1957, pp. 145-154. Analysis of a concentrated source of heat intensity, variable in a harmonic manner, acting at the point A which constitutes the origin of the coordinate system. The action of this source results in a time-variable temperature and stress field (T and σ_{ij}, respectively) both of which vary in a harmonic manner. It is assumed that the frequency of vibration of the heat source is insignificant, so that the phenomenon under consideration can be treated as quasi-static.

THEORY OF AIRCRAFT STRUCTURAL MODELS SUBJECT TO AERODYNAMIC HEATING AND EXTERNAL LOADS. W. J. O'Sullivan, Jr. US, NACA TN 4115, Sept., 1957. 48 pp. Dimensional

analysis of the problem of investigating the simultaneous effects of transient aerodynamic heating and external loads on aircraft structures. Such investigations are undertaken to determine the ability of the structure to withstand flights to supersonic speeds. Results of the present study indicate that a structural model can be built which has the required similitude with respect to flow of heat through it, thermal stresses and deformations, and stresses and deformations due to external loads. For the conditions of negligible angular velocity and angular acceleration, the requisite simulation of in-flight heating and cooling phenomena is shown to be producible automatically by aerodynamic means.

ANALYSIS OF DYNAMIC CREEP CONSIDERING STRAIN RATE EFFECTS. F. H. Vitovec. USAF WADC TR 57-104 [AD 130762], May, 1957. 16 pp. 24 refs. Discussion and classification of the dynamic creep behavior of a number of materials, with emphasis on the use of the stress-range diagram, derived from the creep rate-stress relationship under static load, for determining the acceleration or retardation of dynamic creep. Special consideration is given to the effect of superposition of strain rate and creep rate. Retardation is attributed to aging effects and to the strain-rate effects caused by alternating-stress frequency while acceleration is attributed to metallurgical changes and overtemperature at very high frequencies.

EXPERIMENTAL INVESTIGATION OF CREEP BENDING AND BUCKLING OF THIN CIRCULAR CYLINDRICAL SHELLS. Burton Erickson, S. A. Patel, F. W. French, Samuel Lederman, and N. J. Hoff. U.S., NACA RM 57E17, July 23, 1957. 30 pp. Description of experimental equipment and results of tests on 43 cylinders of 5052-0 aluminum alloy subject to bending moments at a constant temperature of 500°F. All the cylinders failed by buckling, and the time elapsed between load application and collapse is measured.

THERMAL STRESSES IN AN INFINITE, HOLLOW CASE-BONDED CYLINDER. S. A. Zwick. Jet Propulsion, Aug., 1957, pp. 872-876. Derivation of formulas relating thermal stresses to the temperature distribution in an infinitely long, hollow cylinder, bonded at its outer surface to a cylindrical shell, when the temperature of the outer shell is suddenly changed. Approximate relations are then obtained for the case of a thermally thin, but elastically thick, shell corresponding to the practical configuration of a plastic propellant "grain," case-bonded to a metallic shell. It is argued that, for the heat problem considered, the stresses will be monotonic functions of time and hence, the maximim stresses will occur either initially or finally. The solutions presented are expected to be applicable also for approximating the stresses in a long but finite cylinder in regions where end effects can be neglected.

THERMODYNAMICS

CHARACTERISTICS AND SOUND SPEED IN NONISENTROPIC GAS FLOWS WITH NONEQUILIBRIUM THERMODYNAMIC STATES. E. L. Resler, Jr. J. Aero. Sci., Nov., 1957, pp. 785-790. OSR-supported development of a theory extending the method of characteristics to flow problems involving lagging heat capacities and/or finite chemical reaction rates. Special cases appropriate to present high-speed flow problems are considered in more detail - namely, heat-capacity lag and dissociation of a gas made up of diatomic molecules. The theory is easily adaptable to the usual finite-wave approximation used for computations.

THERMODYNAMIC PROPERTIES OF GASES: EQUATIONS DERIVED FROM THE BEATTIE-BRIDGEMAN EQUATION OF STATE ASSUMING VARIABLE SPECIFIC HEATS. R. E. Randall. USAF AEDC TR 57-10 [AD 135332], Aug., 1957. 44 pp. Development of calculation procedures for isentropic expansions and flow through normal shock waves. The increase in the specific heats due to the vibration of diatomic molecules is included by assuming the molecules to be perfect harmonic oscillators.

TEMPERATURES AND THERMAL STRESSES IN TRANSPIRATION-COOLED POWER-PRODUCING PLATES AND TUBES. P. J. Schneider. Jet Propulsion, Aug., 1957, pp. 882-889. 10 refs. Presentation of solutions for the local temperature, mean temperature, efficiency, surface temperature difference, and thermal stress in transpiration-cooled, porous plates and tubes generating uniform distributed heat. Eight special cases are considered, four of which refer to the conventional case of the nongenerating, porous materials.

Combustion

TEMPERATURE STABILITY OF THE LAMINAR COMBUSTION WAVE. J. F. Wehner and J. B. Rosen. Comb. & Flame, Sept., 1957, pp. 339-345, 10 refs. OSR-supported consideration of a solution for a simplified form of the linearized time-dependent energy equation of a laminar flame, in order to develop a criterion for the stability of such a flame. It is shown that for this energy equation the stability is determined by the behavior of the concentration perturbation. The results also demonstrate that it is not justified to assume that the solution to any particular steady-state flame equation is always stable.

A METHOD FOR DETERMINING MINIMUM IGNITION ENERGIES: RESULTS FOR A NEO-PENTANE-AIR MIXTURE. I. W. Wolf and V. T. Burkett. Comb. & Flame, Sept., 1957, pp. 330-338. USAF-sponsored presentation of a technique involving the use of repeated pulsed arcs having near-square wave form as a means for controlling and measuring the energy input as a function of time. The pulses are spaced wide enough apart so

that there is sufficient time for dissipation of the thermal energy in the inter-electrode gap. Details of circuitry, electrodes, and fuel system are given.

DETONATIONS IN GASEOUS FUMING NITRIC ACID-HYDROCARBON MIXTURES. D. H. Wayman and R. L. Potter. Comb. & Flame, Sept., 1957, pp. 321-329. 12 refs. ARDC-sponsored measurement of detonation velocities and determination of detonatable composition ranges for gaseous mixtures of fuming nitric acid with three hydrocarbons, n-heptane, methylcyclopentane, and toluene, and for fuming nitric acid/n-heptane mixtures diluted with up to 60 vol. % nitrogen.

I - PREDICTING THE LAMINAR FLAME SPEED IN GASES WITH TEMPERATURE-EXPLICIT REACTION RATES. D. B. Spalding. Comb. & Flame, Sept., 1957, pp. 287-295. Presentation of a method for calculating flame velocities without solving a differential equation. The procedure is accurate to well within 1% in most cases, and relies on a property of the flame equations discovered by examination of numerous exact solutions. Graphs are presented for a wide range of parameters to permit estimation of the effect of departures from normality in diffusion coefficients on the flame velocity. The graphs are valid for cases of single-step reaction, of chain reactions obeying the steady-state approximation, and of simple chain-branching reactions.

EXTRACTION OF IONS FROM A FLAME. J. Deckers and A. van Tiggelen. Comb. & Flame, Sept., 1957, pp. 281-286. EOARDC-FNRS-supported and sponsored description of the extraction apparatus used in a new technique for studying ionization in flames. The technique is based on the extraction of ions from a flame and their separation from the burnt gases. The extracted ions are successfully produced in a vacuum of 10^{-5} mm. of mercury. Indications are given concerning the concentration of the ions in a flame, as measured by this means.

AN INVESTIGATION OF THE BEHAVIOUR AND REACTION MECHANISMS OF NITRIC ACID-HYDROCARBON FLAMES. M. H. Boyer and P. E. Friebertshauser. Comb. & Flame, Sept., 1957, pp. 264-280. 22 refs. WADC-supported description of an apparatus for producing nitrogen and supported bunsen flames. Data are presented on the flame speed, flashback and blow-off limits, emission spectra, and analysis of combustion products, for flames burning mixtures of nitric acid vapor and propane or butane. A possible interpretation in terms of the reaction sequence through the combustion wave is presented.

II - ONE-DIMENSIONAL LAMINAR FLAME THEORY FOR TEMPERATURE-EXPLICIT REACTION RATES. D. B. Spalding. Comb. & Flame, Sept., 1957, pp. 296-307. Presentation of several exact solutions for flames with normal diffusion and with reaction rate explicit in temperature. It is shown that, when the eigenvalue is defined in terms of the temperature-mean reaction rate, its value depends only on the position of the centroid of the reaction-rate function. Various approximate theories are evaluated, with Wilde's emerging as the most satisfactory. The latter method is developed to provide general relations for the effect of reactant and radical diffusion coefficients on the flame velocity.

A FLOW REACTOR FOR HIGH TEMPERATURE REACTION KINETICS. L. Crocco, I. Glassman, and I. E. Smith. Princeton U., Dept. Aero. Eng. Rep. 398 (AFOSR TN 57-373) [AD 132445], June 7, 1957. 7 pp. Description of a flow reactor designed to study the reaction kinetics of propellants at high temperatures. In principle, the apparatus consists of a tubular duct in which a high-temperature stream of inert gas flows. A secondary cold stream of monopropellant or oxidizer mixture is introduced and mixed rapidly, thus simulating a rocket combustion chamber without the complication of recirculation. Downstream of the injection point reaction begins and continues until all the reactants are consumed. By varying the velocity of the inert carrier gas, the reaction zone may be extended over any desired length. When only a small quantity of the reactants - compared with the mass flow of the carrier - is introduced, the decrease in temperature due to the mixing of the two streams is small, as is the increase in temperature due to the exothermic reaction.

Heat Transfer

ON THE CONVECTION OF HEAT FROM CYLINDERS IMMERSED IN A LOW-SPEED STREAM OF INCOMPRESSIBLE FLUID. S. Tomotika and H. Yosinobu. J. Math. & Phys., July, 1957, pp. 112-120. derivation of the exact solution for the equation which was solved only approximately by Piercy and Winney. The exact expression for the total heat-transfer from the surface of the cylinder is determined. An expansion formula, correct to a third approximation, is also obtained from the exact expression. Numerical values of the total heat transfer are computed by the exact and expansion formulas, and are compared with those calculated by using the corresponding Piercy and Winney's approximate formulas for wall and large velocities.

TURBULENT CONVECTION OVER A HEATED HORIZONTAL SURFACE. D B. Thomas and A. A. Townsend. J. Fluid Mech., July, 1957, pp. 473-492. Investigation to provide experimental material for the testing of existing theories of convection and the development of new ones. Detailed measurements are made of the temperature field in natural convection above a heated horizontal surface in air, with and without a cold upper boundary. Using a variety of experimental techniques, it is possible to measure heat transfer, mean temperature profiles, mean squares of the temperature fluctuations, and the autocorrelation functions of the temperature fluctuations. The results are compared with the similarity theory of Priestley and the neutral stability theory of Malkus. Both of these theories lead to the conclusion that, for convection between parallel planes at high Rayleigh

Numbers, nearly the whole of the mean temperature variation occurs in comparatively thin surface layers whose mutual interaction is small.

HEAT TRANSFER IN TURBULENT PIPE FLOW. R. R. Hunziker. Reed Res., Inc., RR-1167-B TN 1 (AFOSR TN 57-219) [AD 126517], Apr. 14, 1957. 77 pp. 50 refs. Analysis of heat transfer from turbulent flow in pipes and between parallel plates. The corresponding boundary-value problems for temperature distribution in circular pipe and parallel plates are solved by application of Laplace's transformation. The use of Pai's velocity and correlation distribution allows a consistent determination of the eddy diffusivity of heat ϵ_h. A new and better fitting to the experimental Nusselt Number data for liquid metals is obtained.

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DESIGN CONSIDERATIONS OF TWO LARGE LIQUID ROCKET SLED PUSHER VEHICLES. H. Davies and D. S. Smith. Jet Propulsion, Sept., 1957, pp. 999-1, 006. Discussion of propellant selection, power-plant system, vehicle structure, and control system for two vehicles, one transonic and the other supersonic. The two vehicles are developed to propel test sleds mounting large-size, full-scale aircraft components or structures over a wide range of velocities up to Mach 2.

LIQUID ROCKETS FOR SUPERSONIC SLEDS. C. E. Roth Jr. and H. M. Poland. Jet Propulsion, Sept., 1957, pp. 1, 006-1, 011. Discussion of the preliminary design phase for a sled considering the impulse-to-weight ratio of the rocket and sled systems, together with drag, track length, and track friction. Additional requirements include the need for variable duration, variable thrust, repeated operation, command shutdown, and jail-safe design. The static and dynamic test programs are fully outlined.

SUPERSONIC TRACK FACILITIES AT THE NAVAL ORDANCE TEST STATION. Appendix - SNORT CARRIAGE DESIGN. B. R. Egbert and D. P. Ankeney. Jet Propulsion, Sept., 1957, pp. 985-991. Discussion of the three high-speed tracks at China Lake. The telemetry and photography instrumentation is described and the operation of the basic measuring system to find sled position vs. time is explained. The carriage design is studied with emphasis on the importance of correct initial design study.

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DESIGN CONSIDERATIONS FOR TILT-WING TYPE VTOL AIRCRAFT. B. W. McCormick, Jr., and Joseph Mallen. (AHS 3rd Annual Western Forum, Dallas, Oct. 9, 1956.) AHS J., July, 1957, pp. 49-55. Comparison between a tilt-wing, propeller-driven VTOL aircraft and a conventional helicopter - both designed to a common mission. Gross weight, general design features, and basic aerodynamic parameters are discussed briefly, as is the problem of propeller aerodynamics. Treatment includes determination of the motion of the aircraft during transition from the hovering to the airplane state, or vice versa, and investigation of the behavior of the aircraft following a partial or complete power failure in the hovering state.

WATER-BORNE AIRCRAFT

IMPACT-LOADS INVESTIGATION OF CHINE-IMMERSED MODEL HAVING A CIRCULAR-ARC TRANSVERSE SHAPE. P. M. Edge, Jr. US, NACA TN 4103, Sept., 1957. 35 pp. Test results on a model having a circular-arc cross section with a radius of one beam. The coefficients of loads and motion are presented in figures as a function of trim and initial flight-path angles. The circular-arc model experiences loads about 10% greater than those predicted by theory for this configuration. These loads are as much as 12% less than those measured under similar conditions for a model with concave-convex cross section having a similar effective angle of dead rise.

IMPACT-LOADS INVESTIGATION OF A CHINE-IMMERSED MODEL HAVING A LONGITUDINALLY CURVED BOW AND A V-BOTTOM WITH A DEAD-RISE ANGLE OF 30°. P. M. Edge, Jr., and J. S. Mixon. US, NACA TN 4106, Sept., 1957. 24 pp. Experimental investigation made in smooth water at a beam-loading coefficient of 18.8 with the trim angle held fixed throughout each impact. Impacts with forward speed are made over a range of trim angles from -3° to 30°, and initial flight-path angles from 3.5° to 27°. Data are presented for determining the extent of bow immersion during the impacts. The curved bow is found to be not immersed at the high trim angles (15° and 30°), only slightly immersed at angles of 6° and 9°, and almost totally immersed at turn angles of 3° or below. The maximum impact loads are shown to be in substantial agreement with loads predicted by theory for the non-bow-immersed case.

WIND TUNNELS & RESEARCH FACILITIES

JET SIMULATION IN THE WIND TUNNEL. E. E. Covert. MIT NSL TR 252, July, 1957. 14 pp. Brief discussion indicating that simulation in subsonic tests is relatively easy to achieve and that either hot or cold jets are satisfactory. In the subsonic test, the proper similitude parameter is the thrust coefficient. It is suggested that in supersonic tests two suitable approximations can be made. If the field near the jet is of importance, the flow turning angle and the jet Mach Number govern the flow.

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Bruce E. Tinling and Armando E. Lopez. **II—Lateral and Directional Characteristics.** Howard F. Savage and Bruce E. Tinling. *U.S., NACA TN 4041, TN 4042*, July, Aug., 1957. 85, 82 pp. 20 refs.

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An Approximation to the Slow Mode of Longitudinally Disturbed Motion of an Aircraft in Level Flight. A. W. Thorpe. *Gt. Brit., ARC R&M 2907* (Sept., 1951), 1957. 27 pp. BIS, New York, $1.44.

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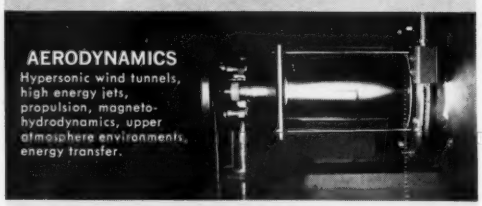
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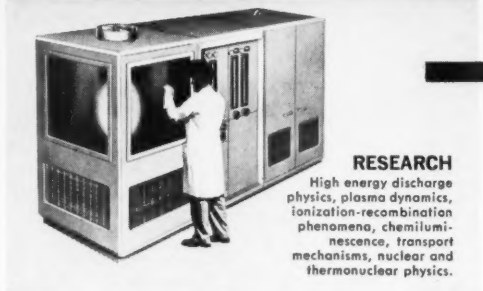
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Aeroelasticity

The Theoretical Determination of Normal Modes and Frequencies of Vibration. Appendix I—**Bibliography of Methods of Determination of Normal Vibration Modes and Frequencies.** Appendix II—**Ducan's Displacement Functions.** Appendix III—**The Escalator Method.** I. T. Minhinnick. (*Gt. Brit., RAE Rep. Struc.197*, Jan., 1956; *NATO AGARD Structures and Materials Panel, Washington, Apr. 10–17, 1956.*) *NATO AGARD Rep. 36*, Apr., 1956. 39 pp. 96 refs.

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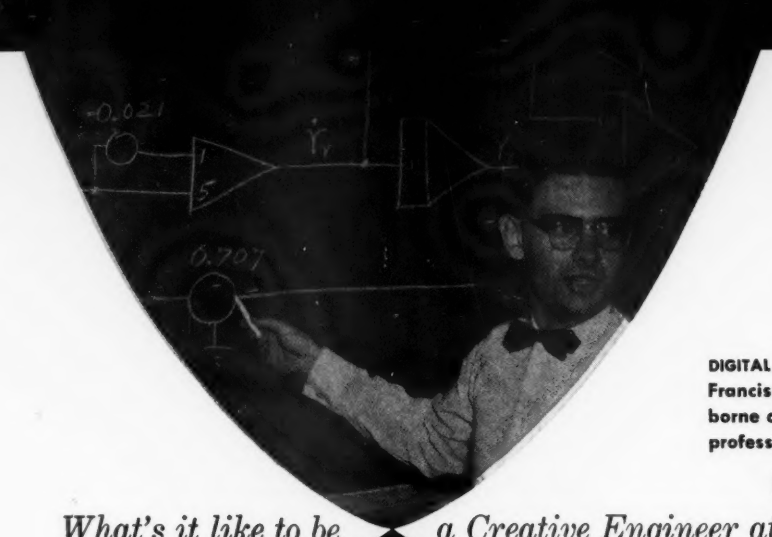

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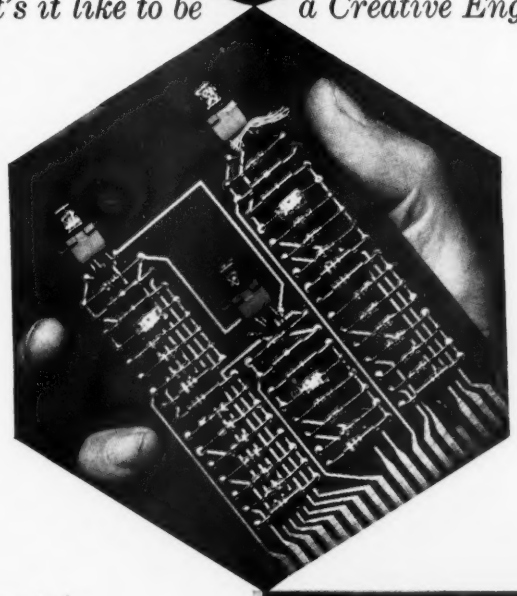

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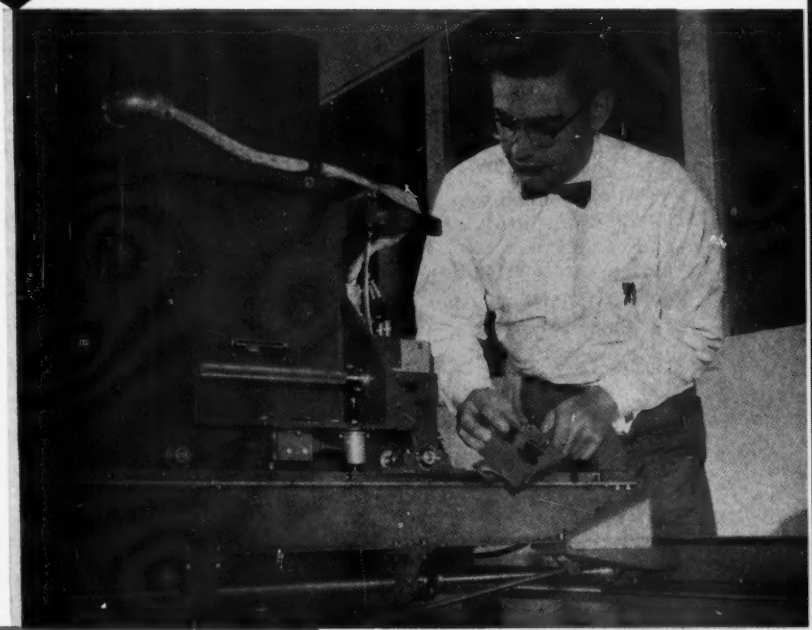

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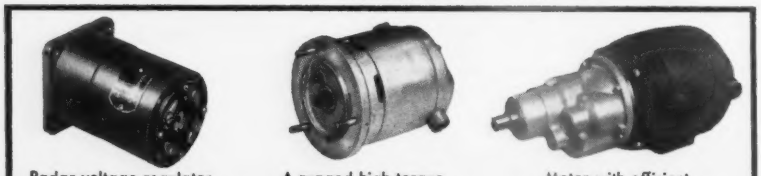

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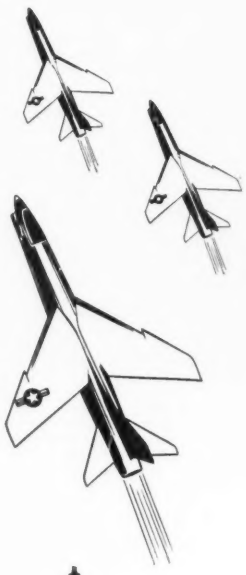

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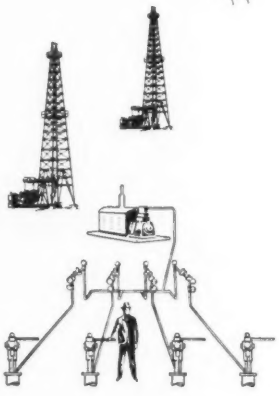

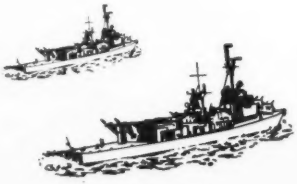

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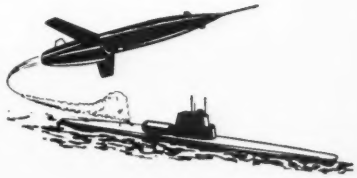

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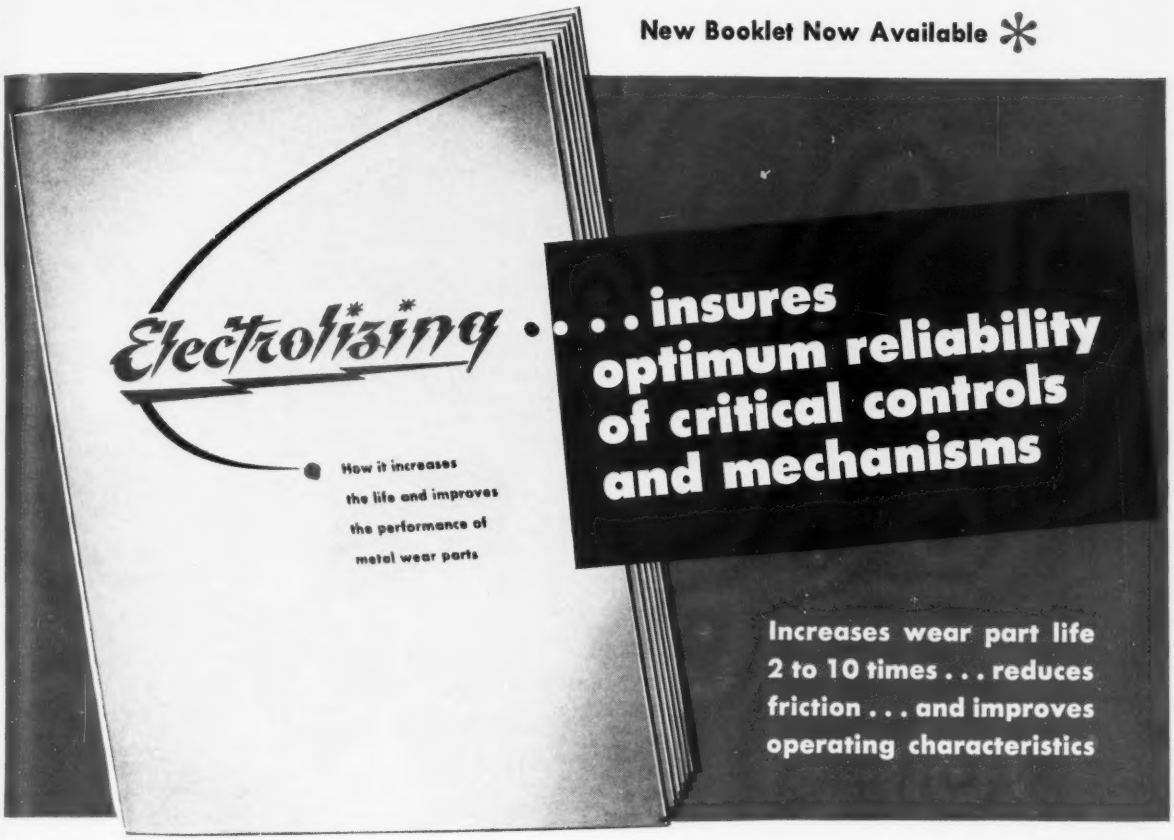
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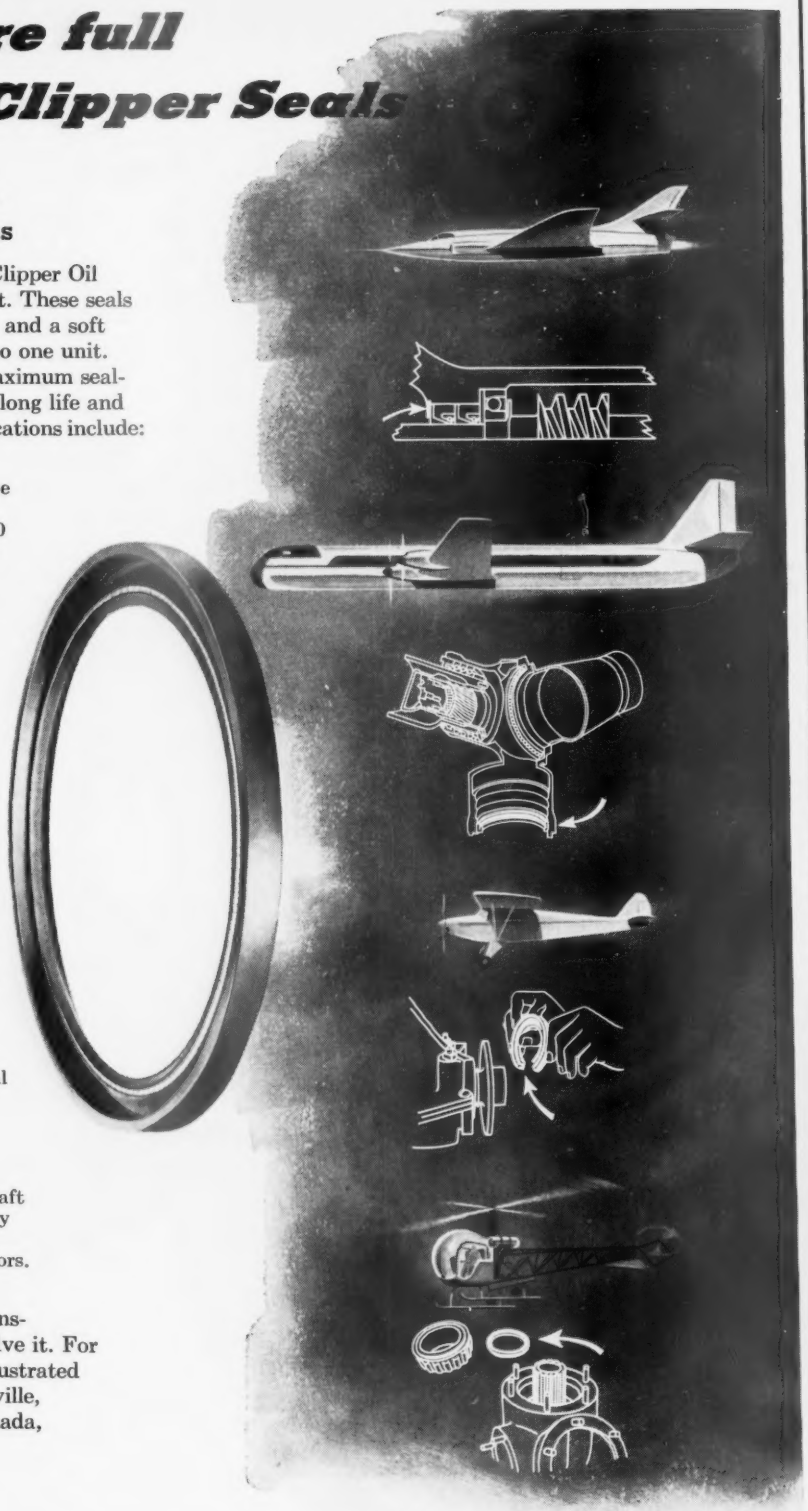

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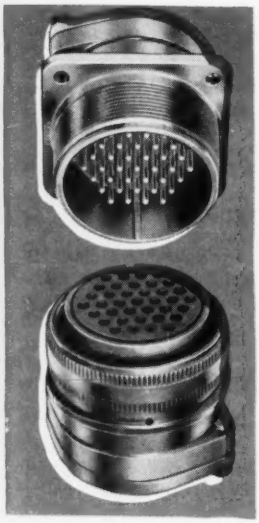

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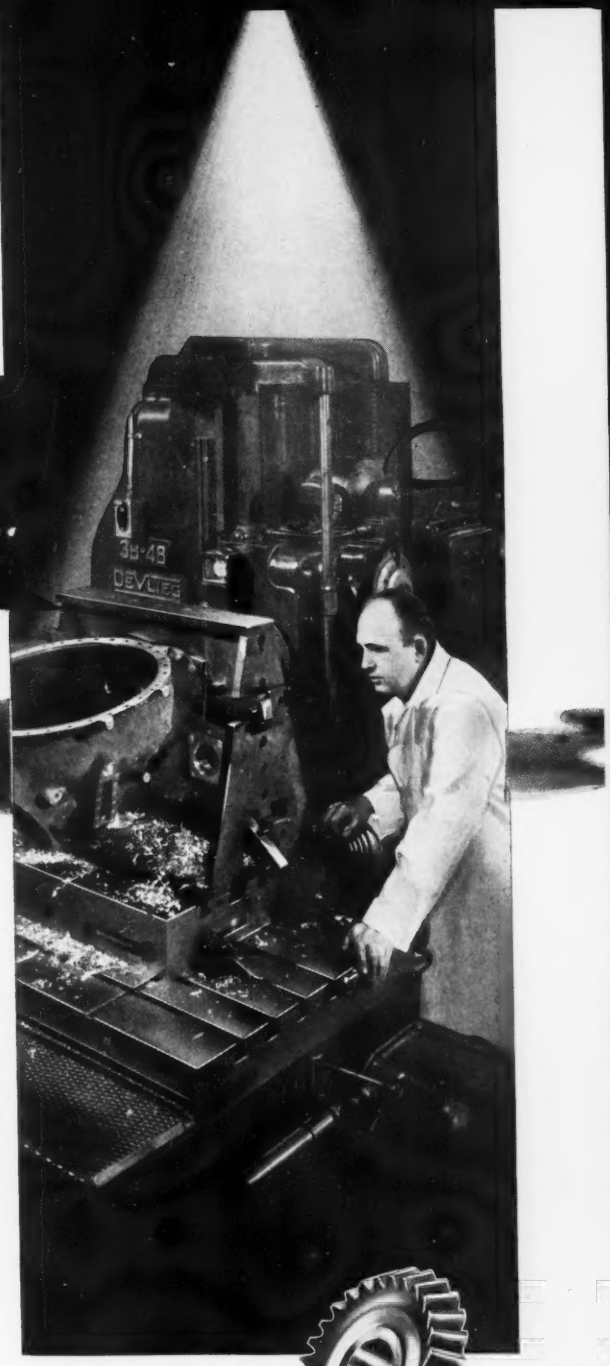

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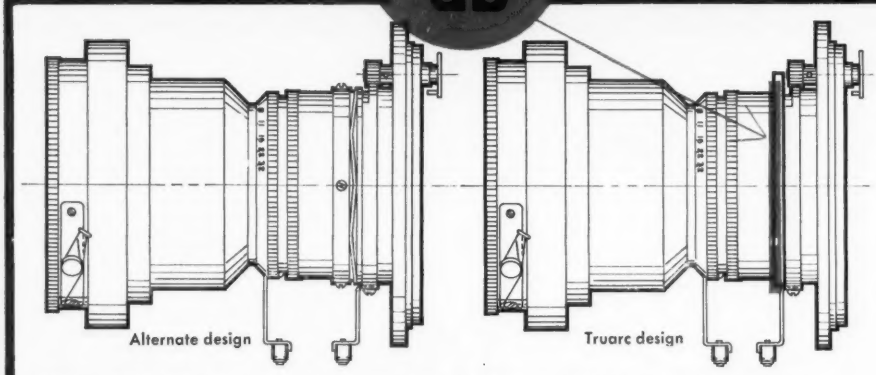

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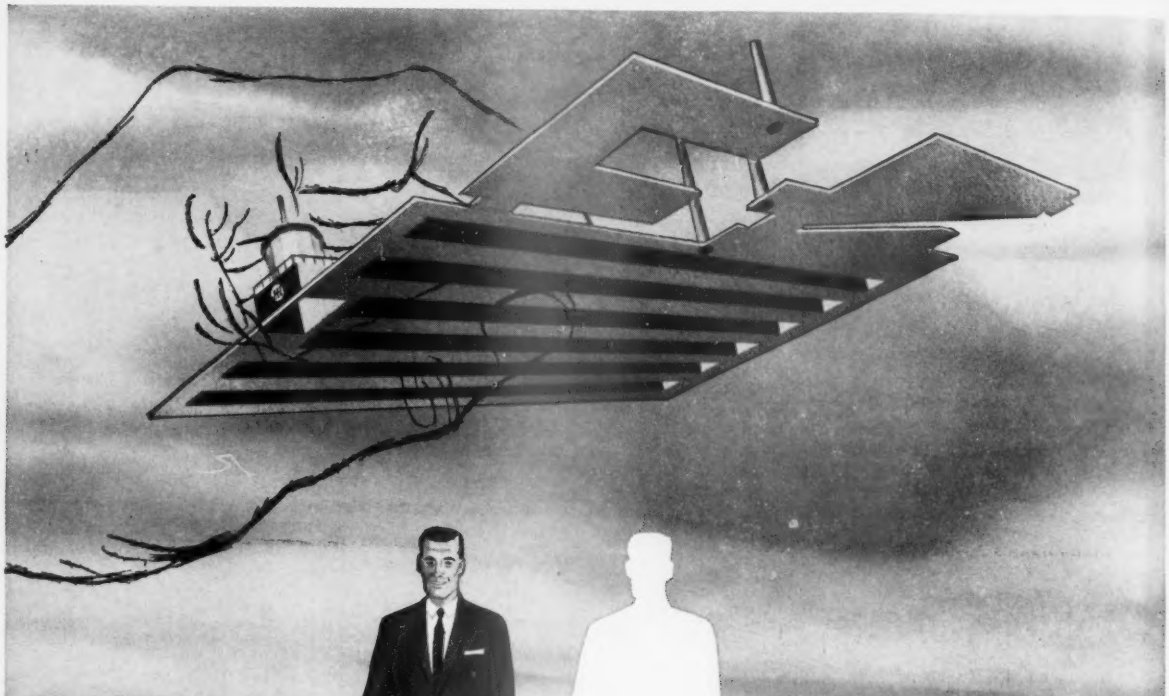

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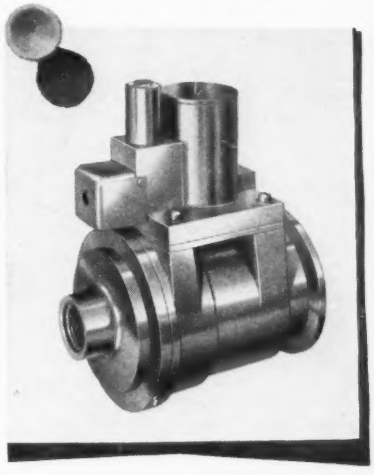

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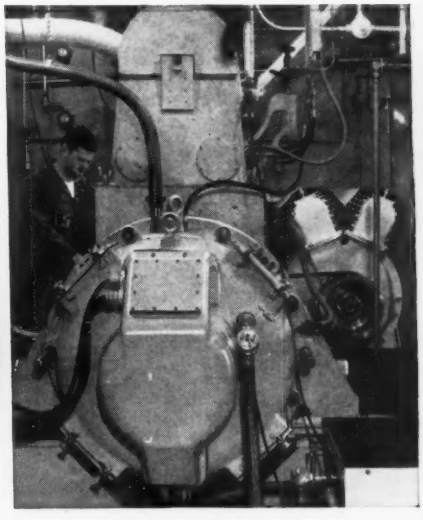

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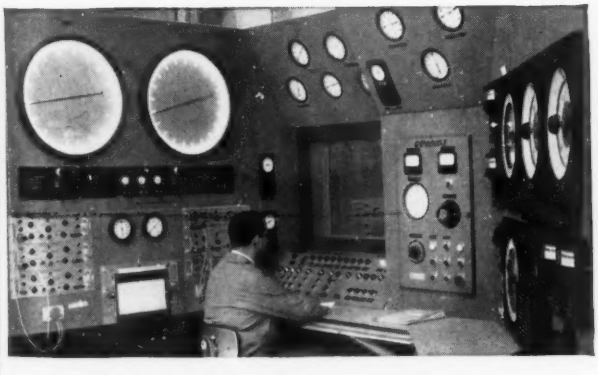

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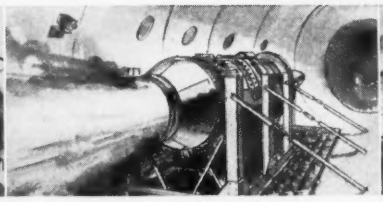

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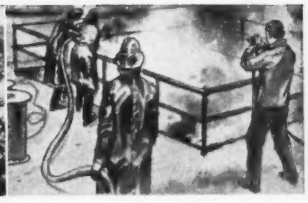

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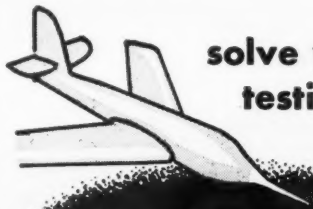

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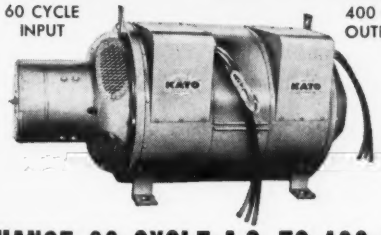

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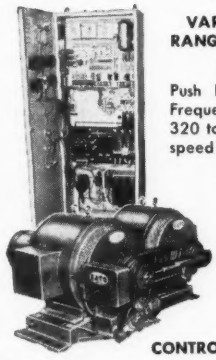

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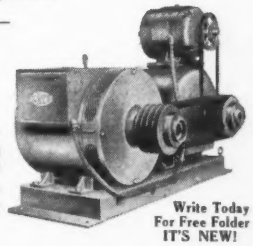

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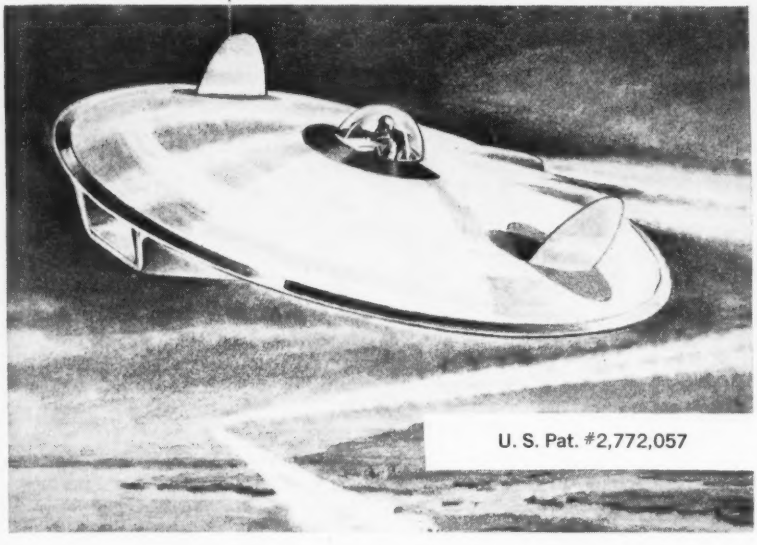

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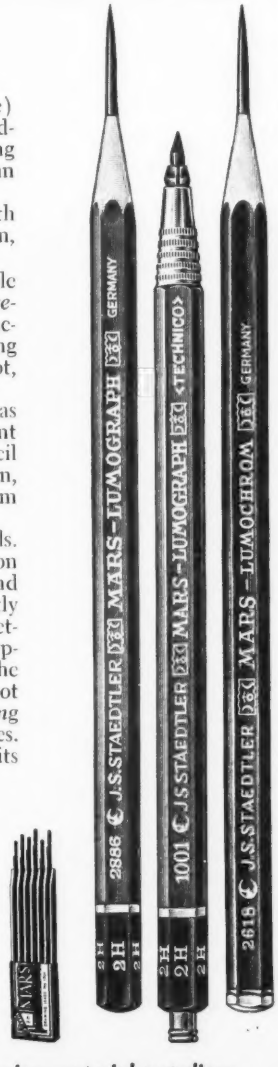

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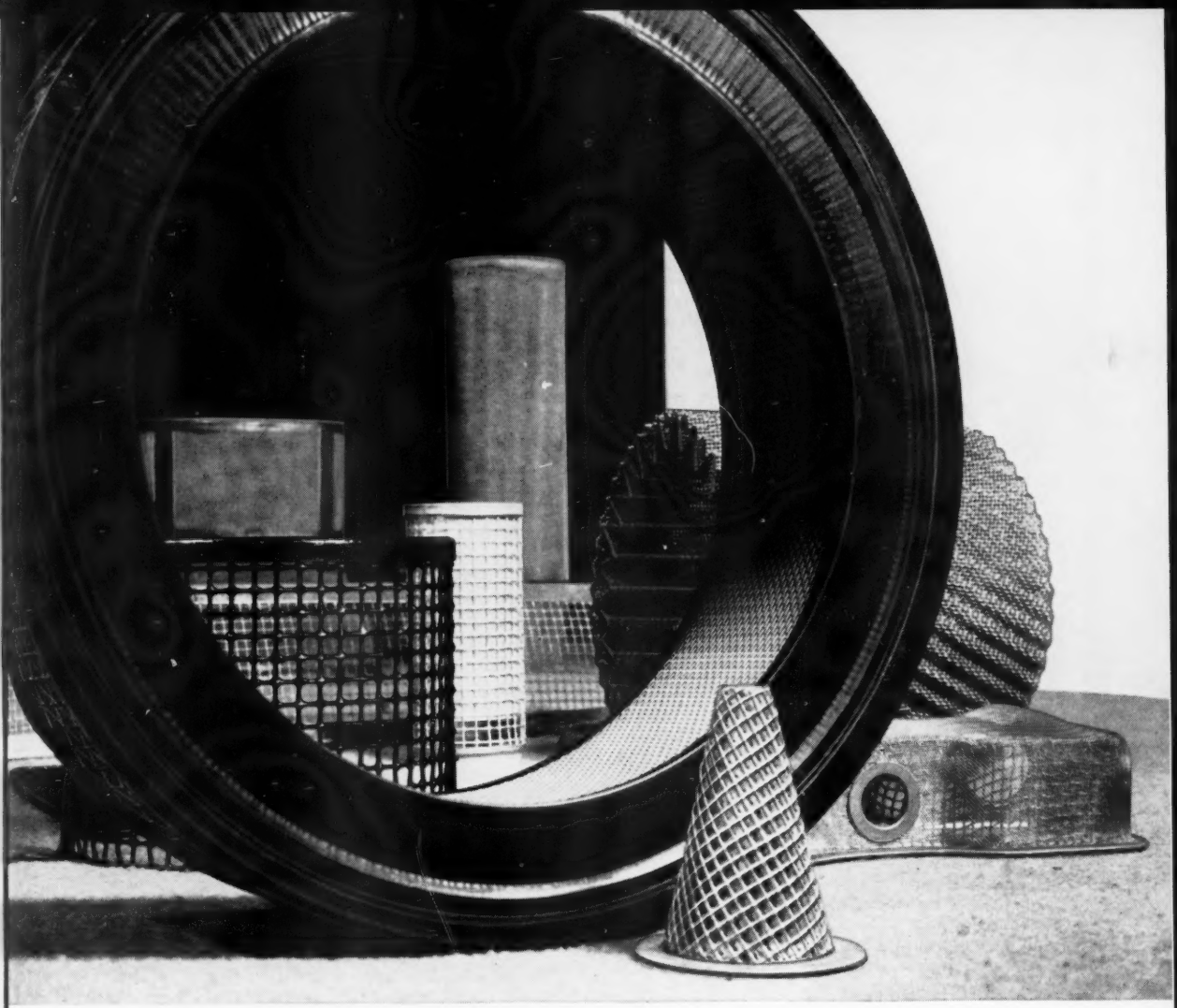

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VTOL & STOL

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The Operation of the N. P. L. 18″ x 14″ Wind Tunnel in the Transonic Speed Range. I. M. Hall. *Gt. Brit., ARC CP 338*, (Jan. 10, 1955) 1957. 21 pp. 11 refs. BIS, New York, $0.54. Description of slotted liners used to operate in the transonic speed range. Power requirements, preliminary calibration results, and some flow surveys are also presented.

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Tunnel for a Powerplant. R. Kaisner and M. Johnson. *CEC Recordings*, July-Aug., 1957, pp. 12–15. Description of the

instrumentation and data processing system of the propulsion tunnel at the Arnold Engineering Development Center.

Opening of the R.A.E., Bedford. I, II, III. *The Engr.*, July 5, 12, 19, 1957, pp. 19–23; 52–54; 95–97. (Also in *Flight*, July 5, 1957, pp. 18–20, and *The Aeroplane*, July 5, 1957, pp. 16–18.) Discussion of flying and static displays on the opening day, and description of the wind-tunnel facilities, the power plant, and the flying field with special equipment to represent carrier landings and launchings.

Note on Strain Gauge Recording Equipment for the R.A.E. Intermittent Supersonic Wind Tunnels. K. G. Winter and E. J. Petherick. (*Gt. Brit., RAE TN Aero. 2461*, June, 1956; *NATO AGARD Wind-Tunnel & Model-Testing Panel, Brussels, Aug. 27–31, 1956.*) *NATO AGARD Rep. 64*, Aug., 1956. 11 pp. Description of the simple interim system in use in the R.A.E. Intermittent Wind Tunnel Plant and of a more sophisticated system similar to that proposed by Lukasiewicz.

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Methods of Interferometry Applied to the Visualization of Flows in Wind Tunnels. R. Chevalerias, Y. Latron, and C. Veret. *OSA J.*, Aug., 1957, pp. 703–706. Description of two optical setups, the first for an overall study of the flow over a model and the second for a detailed analysis of a small region.

Design and Construction of Wind Tunnel Models. Joseph J. Muncey and David M. Pote. (*NATO AGARD Wind-Tunnel & Model-Testing Panel, Rome, Feb. 20–25, 1956.*) *NATO AGARD Rep. 20*, Feb., 1956. 20 pp. Discussion of model design features and methods of construction for coping with the problems posed by the around-the-clock schedule of the major wind tunnel at the Cornell Aeronautical Laboratory.

Model Selection and Design Practices Applicable to the Development of Specific Aircraft. Donald D. Baals. (*NATO AGARD Wind-Tunnel & Model-Testing Panel, Rome, Feb. 20–25, 1956.*) *NATO AGARD Rep. 21*, Feb., 1956. 27 pp. 14 refs. Discussion of factors pertinent to a specific model-development program and of the major aerodynamic and mechanical requirements of model design. Five basic-development and five special-purpose models are considered as the typical array necessary for the development of a present-day supersonic fighter.

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Members Elected

(Continued from page 88)

Taynton, Paul, B.S. in Ae.E., Aerodynamicist, Thieblot Aircraft Co., Div. of Vitro Corp. of America.

Walacavage, Robert L., B.S. in Ae.E., Assoc. Engr., Aerodynamics, Convair Div. (San Diego), General Dynamics Corp.

Washburn, Allen C., B.S., Assoc. Engr., The Martin Co. (Orlando).

Wells, Otis D., B.S. in Ae.E., Graduate Student and Instructor, Texas A & M College.

Whittington, Paul D., B.S. in Ae.E., Jr. Mech. Engr., Guided Missile Div., Firestone Tire & Rubber Co. (Los Angeles)

Willey, Clarence E., B.S. in Aviation Tech., Draftsman and Shop Leadman, The Jamieson Corp.

Willoughby, Leon, B.S. in Ae.E., Assoc. Engr., Northrop Aircraft, Inc.

Wood, Fred D., Jr., B.S. in M.E., 2nd Lt., Reports and Analysis Officer (Maintenance), USAF (Lincoln AFB).

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Comptes Rendus des Journées Internationales de Sciences Aeronautiques, 27–29 mai 1957, Paris (Proceedings of the International Meeting on the Aeronautical Sciences, May 27–29, 1957, Paris). Part 1. Paris, Office National d'Etudes et de Recherches Aéronautiques (ONERA), July, 1957. 162 pp., illus., figs.

Contents: Introduction, Maurice Roy. The Role of Dynamic Techniques in the Design and Development of High Speed Aircraft, R. Richard Heppe. Inlet-Engine Matching and Control Systems for Supersonic Airplanes, Carl F. Schueller. Interaction de l'écoulement externe et de l'écoulement interne à la sorti d'un réacteur, aux vitesses transsoniques et supersoniques (Interaction between External and Internal Flow at the Exit of a Jet Engine at Transonic and Supersonic Speeds), P. Carrière. Inlet Flow Distortion Index, J. S. Alford. Automatic Control of Aircraft, Joseph Bicknell, E. Eugene Larabee, Robert C. Seamans, Jr., and H. Philip Whitaker. Schwingungen in Verdichtern (Oscillations in Compressors), H. Söhngen and A. W. Quick. Some Design Problems in Inertia Navigation, W. Cawood.

1957 First Award Papers; IAS Student Branch Paper Competition. New York, Minta Martin Aeronautical Student Fund, Institute of the Aeronautical Sciences, 1957. 125 pp., illus., diagrs.

The papers presented in this third annual edition of the prize-winning contributions of IAS Student Members were prepared and delivered at eight IAS regional conferences held in the spring of this year. Each paper was judged a first-place winner by a board of judges and was published by the IAS as a means of providing additional encouragement and incentive to the engineering student and assisting him in defining his own professional goals.

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Flight To-Day. J. L. Naylor and E. Ower. 4th Ed. London, New York, Oxford University Press, 1957. 184 pp., illus., diagrs., tables. $1.55.

The purpose of this volume is to furnish the general reader and the student of aeronautics with an introduction to the art of flying, the types of aircraft in service today, and the technical factors involved in both civil and military flying. An appendix of famous flights dating from the late 1700's to the present is included at the end of the text.

AIR TRANSPORTATION

New York's Overseas Air Travelers; Report of a Survey Conducted in Collaboration with the Overseas Scheduled Airlines—April through October 1956. New York, Forecast and Analysis Division, Aviation Department, The Port of New York Authority. July, 1957. 132 pp., diagrs., tables.

CLIMATOLOGY

The Climate Near the Ground. Rudolf Geiger. 2nd Rev. Ed. Translated from the German by Milroy N. Stewart and others. Cambridge, Mass., Harvard University Press, 1957. 494 pp., illus., diagrs., tables. $6.00.

This is a second printing of an edition that was originally published in translation in 1950. The text has been thoroughly revised and expanded to present the results of the many advances made in this field in the past 20 years, and the numbered references cited in the original text have been increased by an additional 500 papers and books relating to the current status of microclimatology.

ELECTRONICS

Transistor Circuit Engineering. Edited by Richard F. Shea. New York, John Wiley & Sons, Inc., 1957. 468 pp., diagrs., tables. $12.

Written by nine members of the General Electric Company staff, this work on basic transistor theory and its application to typical circuits provides the necessary tools for doing actual circuit design and developing usable circuits in all potential fields of application. The reader is shown how to build workable audio amplifiers, radio frequency amplifiers, etc., using available transistors, and how to combine these elements into radio receivers, television sets, and high-fidelity audio systems. The twelve chapters of text are devoted to characteristics and characteristic curves; equivalent circuits; bias and its stabilization; audio amplifiers; d.c. amplifiers and their applications; tuned amplifiers; video amplifiers; oscillators; modulation, mixing, and detection; transient response and pulse circuits; systems; and special circuits.

NEL Reliability Design Handbook. San Diego, Calif., U.S. Navy Electronics Laboratory, 1954. Washington, Distributed by OTS. 200 pp., illus., diagrs., tables. $3.00. (PB 121839).

Intended to serve as a medium through which information on new materials, processes, and techniques as well as design aids and reliability can be disseminated, this handbook has been issued by the NEL as a first step toward achieving greater simplicity, economy, and reliability in electronics equipment developed for the Navy. Although it is primarily designed for use by the engineers, scientists, and mechanics of the NEL, much of the information contained in these pages will be of value to other Government laboratories and to contractors. The basic book will be enlarged and kept up to date by means of loose-leaf insertion sheets, which will be distributed to subscribers at frequent intervals. In addition to NEL-originated material, the handbook will also contain current reliability and standardization data from the Bureau of Ships, other Government organizations, and contractors. Digests of important reliability findings and proposed design standards will appear regularly.

MACHINE ELEMENTS

Fasteners Handbook. Julius Soled. New York, Reinhold Publishing Corporation, 1957. 430 pp., illus., diagrs., tables. $12.50.

More than 300 standard and proprietary industrial fasteners are described in this reference volume including rivets, inserts, screws, bolts, studs, nuts, washers, retaining rings, pins, nails, metal stiching, quick release fasteners, masonry anchoring devices, and hose clamps. Each item, verified by the listed manufacturer, is given a full-page description that contains illustrations, features, uses, standard materials, standard sizes, and pertinent comments. Additionally, the author, design engineer for the Signal Corps Engineering Laboratories, points out money-saving applications by relating the use of fasteners in one industry to those of another.

The book closes with a Directory of Fastener Manufacturers, which includes manufacturers and licensees of fasteners referred to in the text, plus those manufacturers of fasteners whose names were available from trade associations. Only those in the United States and Canada have been considered.

MAGNETOHYDRODYNAMICS

Magnetohydrodynamics: A Symposium. Edited by Rolf K. M. Landshoff. Stanford, Calif., Stanford University Press, 1957. 115 pp., illus., diagrs., tables. $4.00.

The increasing interest in the fusion of two disciplines—gas dynamics and electromagnetic theory—which has resulted in a new branch of physical science, magnetohydrodynamics, led the Lockheed Missile Systems Division to sponsor a Magnetohydrodynamics Symposium in its new

laboratory at Palo Alto, Calif., on December 19, 1956. This volume, for the most part, follows the symposium; however, certain alterations have been made in the text, including the replacement of preliminary results as first reported by later, more complete data.

Contents: Section 1, Theoretical Work: (1) An Introductory Discussion of Magnetohydrodynamics, A. R. Kantrowitz and H. E. Petschek. (2) Some Dimensional Aspects of Hydromagnetic Phenomena, W. M. Elsasser. (3) The Build-Up of Large Magnetic Fields Inside Stars, F. Hoyle. (4) Penetration of a Shock Wave into a Magnetic Field. J. M. Burgers. (5) Dynamics of a Pinched Gas, M. Rosenbluth. *Section 2, Laboratory Experiments:* (6) Scaling Laws as an Aid to Experimental Studies, R. K. M. Landshoff. (7) Magnetically Driven Shock Waves: (a) Experiments at U.S. Naval Research Laboratory, A. C. Kolb; (b) Experiments at Lockheed Missile Systems Division, S. W. Kash; (c) Experiments at AVCO, H. E. Petscheck. (8) Shock Waves Passing Through a Magnetic Field Region, A. Kantrowitz. (9) Liquid Sodium Instability Experiment, S. A. Colgate. (10) The Hydromagnetic Wave Guide, W. A. Newcomb.

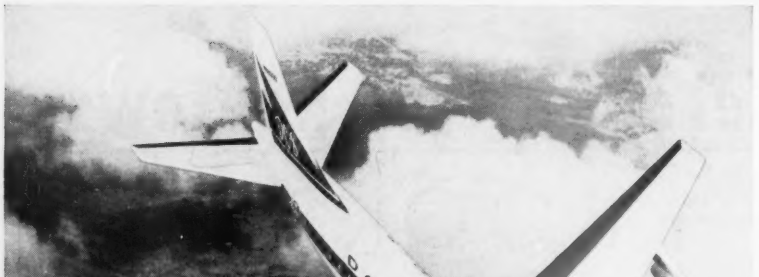
MANPOWER

The Demand and Supply of Scientific Personnel. David M. Blank and George J. Stigler. New York, National Bureau of Economic Research, Inc., 1957. 200 pp., diagrs., tables. $4.00.

Conducted under a grant from the National Science Foundation, this analysis of the factors affecting the technological profession in the United States since the turn of the century attempts to explain the methods by which one can explain movements in the supply and demand for scientific personnel. David M. Blank is Associate Economic Advisor, Columbia Broadcasting System, while George J. Stigler is a member of the research staff at the National Bureau of Economic Research and Professor of Economics, Columbia University.

Contents: 1, A General View of the Technological Professions (1) The Growth of the Technological Professions (2) What Is an Engineer? (3) The Growth of Organized Research. *2, Demand and Supply: Methods of Analysis.* (1) Has There Been a Shortage? A Survey of Earnings. (2) The Bureau of Labor Statistics Method of Prediction of Demand. (3) The Engineers Joint Council Method of Prediction of Demand. *3, Factors Influencing the Demand for Engineers and Chemists.* (1) Industrial Patterns in the Use of Engineers and Chemists. (2) The Role of Government. (3) The Upward Trend of Demand. (4) Short-Run Changes in Demand. (5) The Gross vs. Net Demand for Engineers. *4, The Supply of Engineers.* (1) College-Trained Engineers. (2) Graduate Degrees in Engineering. (3) The Distribution of Bachelor's Degrees by Field. (4) Other College-Trained Entrants into the Engineering Profession. (5) Limitations on the Supply of College-Trained Engineers. (6) Nongraduate Engineers. *5, Supply and Demand for Mathematicians and Physicists.* (1) Demand Factors: (a) Faculty-Student Ratios; (b) The Trend of College Enrollments. (2) The Supply of Mathematicians and Physicists. *Appendix:* A, Engineering Earnings; B, Census Data on Number of Engineers and Chemists, 1890–1950; C, Tables on Engineering Enrollments and Degrees; D, Projections of the Number of Engineering Degrees to 1970; E, Reconciliation of 1940 and 1950 Census Counts of Engineers; F, Tables on Years of School Completed for Engineers, 1940, and Age and Years of School Completed for Engineers and Scientists, 1950; G, Analysis of Rates and Transfer Out of the Engineering Profession for Engineers with Varying Years of Experience; H, The Engineers Joint Council Surveys; I, Advertisements for Engineers. Index.

Professional Engineers' Income and Salary Survey, 1956. Washington, National Society of Professional Engineers, 1957. 44 pp., diagrs., tables. $1.00.



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MATERIALS

Proceedings of the American Society for Testing Materials, Vol. 56, 1956. Philadelphia, A.S.T.M., 1957. 1,498 pp., illus., diagrs., tables. $12.

In addition to summaries of various ASTM meetings throughout the year, the 1956 volume contains the reports of committees charged with studying ferrous and nonferrous metals, cementitious, ceramic, concrete, and masonry materials, and materials of a miscellaneous nature. All technical papers accepted by the Society appear in the *Proceedings*, including those which have been published in the *ASTM Bulletin* or as *Special Technical Publications*. In addition, all separate publications not included in either the *Proceedings* or the *ASTM Bulletin* are listed on the last page of the volume.

Boron and its Isotopes. Compiled for the U.S. Atomic Energy Commission. Niagara Falls, N.Y., Hooker Electrochemical Company, June, 1957. 11 pp., diagrs.

The data supplied give the physical, chemical, and nuclear properties of boron and its isotopes as well as the availability and prices of boron and boron compounds enriched in B^{10}.

Glass Reinforced Plastics. Edited by Phillip Morgan. 2nd Ed. London, Iliffe & Sons, Ltd.; New York, Philosophical Library, 1957. 276 pp., illus., diagrs., tables. $15.

The text of this new edition of a book which first appeared in 1954 has been thoroughly revised and rewritten where necessary. Three of the chapters are new; in these, epoxide resins, the resin injection moulding process, and chemical plant applications are discussed. An appendix has been added which briefly describes a method of examining design detail by means of structural models. The techniques included are the standard commercial production methods, and the major fields of application are the automobile, aircraft, electrical uses, and the chemical plant.

Contents: (1) Glass Fibre Forms and Properties. K. J. Brookfield. (2) The Chemistry of Unsaturated Polyester and Alkyl Resins. C. P. Vale. (3) Polyester Types and Properties. E. M. Evans. (4) Ancillaries for Polyesters. Brian Parkyn. (5) Glass Fibres with Phenolic Resins. N. W. Knewstubb. (6) Silicone, Melamine, and Furane Resins. H. A. Collinson and R. McDowall. (7) Epoxide Resins. W. J. Marmion. (8) Commercial Moulding Processes. G. C. Hulbert. (9) Methods of Mass Production. A. E. Dean. (10) Continuous Resin Injection for Glass Fibre Moulding. J. Rees. (11) Tube and Rod Production. A. R. Henning and B. G. Cuming. (12) Design and Properties of Structures. Lorne Welch. (13) Glass Reinforced Plastics in the Aircraft Industry. Richard Wood. (14) Glass Fibre Laminates in the Electrical Field. J. K. Hyde. (15) Automobile Bodywork and Other Transport Applications. Richard Wood. (16) Polyester/Glass Boat Hulls. P. D. de Laszlo. (17) Chemical Engineering Applications. V. Evans. (18) Miscellaneous Applications. Patrick Moxey. Appendix: Structural Models. Peter H. H. Bishop. Subject Index.

Polyethylene. Theodore O. J. Kresser. (Reinhold Plastics Applications Series, Vol. 1.) New York, Reinhold Publishing Corporation, 1957. 217 pp., illus., diagrs., tables. $4.95.

The present volume is the first of a series stressing the applications of the various types of commercial materials of the plastics industry. Mr. Kresser concerns himself with the applications

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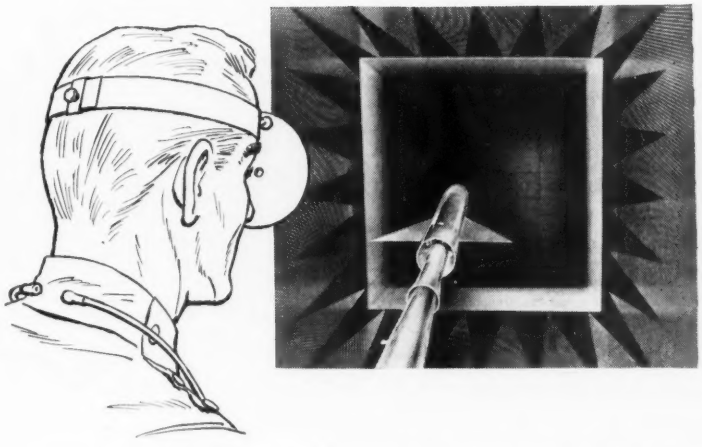

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of polyethylene, how it is produced, how it is made into useful articles, and why this thermoplastic is particularly suited to many applications. The book also includes a brief history of the plastics industry, with special emphasis on the development and future of polyethylene.

MATHEMATICS

Set Theory. Felix Hausdorff. 3rd Ed. Translated from the German by John R. Aumann, *et al*. New York, Chelsea Publishing Company, 1957. 352 pp., diagrs. $6.00.

Contents: (1) Sets and the Combining of Sets. (2) Cardinal Numbers. (3) Order Types. (4) Ordinal Numbers. (5) Systems of Sets. (6) Point Sets. (7) Point Sets and Ordinal Numbers. (8) Mappings of Two Spaces. (9) Real Functions. (10) Supplement. Appendixes. Bibliography. Further References. Index

Basic Mathematics for Radio and Electronics. F. M. Colebrook and J. W. Head. 3rd Ed. London, Iliffe & Sons, Ltd.; New York, Philosophical Library, 1957. 359 pp., diagrs. $6.00.

The chief aim of both the original and the revised parts of this book is to assist those people interested in radio or electronic engineering who find themselves handicapped by their lack of mathematical knowledge. The authors have selected in each branch of the subject under discussion those elementary but fundamental ideas of differential and integral calculus and of vector algebra which have proved to be of practical importance in radio work. The first seven chapters have been retained in their entirety; Chapters 8 and 9, which were contributed by Mr. Head, contain new matter not appearing in the original text.

Contents; (1) Elementary Algebra: The Fundamental Ideas. (2) Indices and Logarithms. (3) Equations: Complex Numbers. (4) Continuity; Limits; Series. (5) Geometry and Trigonometry. (6) The Differential and Integral Calculus. (7) The Application of Mathematical Ideas to Radio. (8) Heaviside's Technique for More Difficult Electrical Problems. (9) Miscellaneous Techniques. Appendix: Answers to Examples. Index.

NUCLEAR ENERGY

Nuclear Engineering. Edited by Charles F. Bonilla. New York, McGraw-Hill Book Company, Inc., 1957. 850 pp., illus., diagrs., tables. $12.50.

Written by twelve authorities in various fields of engineering and science, this reference work discusses the basic principles of the main engineering disciplines involved in the design of nuclear reactor cores and power plants. In each of the twelve fields, the fundamentals are given briefly and clearly, with enough illustrations and advanced specific analysis so that the book is valuable to the working design engineer as well as to the student. Intended as a text for a graduate course for engineers and physics majors, it contains extensive information on the subjects of fluid flow, heat transfer, stress analysis, power cycles, mathematical analysis of plastic flow in thermal stress, design of orifices for protection of parallel coolant channels, and relative evaluation of fuel element shapes and coolants. The editor is Professor of Chemical Engineering and Chairman, Nuclear Engineering Committee, Columbia University.

Contents: (1) Introduction. (2) Nuclear Particles. (3) Nuclear Physics. (4) Particle Detection. (5) Basic Concepts of Radiation Protection. (6) Elementary Reactor Physics. (7) Shielding of Power Reactors. (8) The Flow of Fluids. (9) Heat Removal. (10) Metallurgy of Uranium and Uranium Alloys. (11) Thermal-Stress Analysis and Mechanical Design. (12) Instrumentation and Control. (13) Power Generation. (14) Nuclear-Reactor Types. (15) Legal Aspects of Nuclear Power. Appendixes. Index.

Radiation Shielding. B. T. Price, C. C. Horton, and K. T. Spinney. (International Series of Monographs on Nuclear Energy: Division 10, Reactor Design Physics, Vol. 2.) London; New York, Pergamon Press, 1957. 350 pp., diagrs., tables. $10.

Stressing the physical principles underlying the engineering design of a reactor shield, this textbook treatment of radiation shielding encompasses reactors, betatrons, synchrotrons, and linear accelerators; however, the shielding of very high-energy accelerating machines has been omitted. The various topics under discussion include the biological hazards of nuclear radiations, the attenuation of gamma rays and high-energy electrons, shielding against neutrons and neutron physics, neutron attenuation in thick shields, and the shielding of reactors and radioactive materials. The text is supported by numerous charts, diagrams, tables, and bibliographies.

The authors are all with the Atomic Energy Research Establishment at Harwell.

PRODUCTION

Magnesium Casting Technology. A. W. Brace and F. A. Allen. London, Chapman & Hall, Ltd.; New York, Reinhold Publishing Corporation, 1957. 174 pp., illus., diagrs., tables. $4.95.

The purpose of this volume is to provide founders with an understanding of the basic principles of magnesium founding under one cover which have hitherto been discussed only in numerous published and unpublished papers. An attempt has been made to present objectively both British and American practice against a background of the more basic chemical and physical properties of the metal.

Contents: (1) Introduction. (2) Magnesium Casting Alloys. (3) Magnesium Alloy Melting Practice. (4) Moulding and Core Sands. (5) Production of Sand Castings. (6) Gravity Die-Casting. (7) Pressure Die-Casting. (8) Heat Treatment of Magnesium Alloy Castings. (9) The Inspection of Magnesium Alloy Castings and Notes on Common Defects. (10) Surface Treatment. (11) Applications of Magnesium Castings. Classified Bibliography. Index.

PUMPS

Centrifugal and Axial Flow Pumps; Theory, Design, and Application. Alexey J. Stepanoff. 2nd Ed. New York, John Wiley & Sons, Inc., 1957. 462 pp., illus., diagrs., tables. $12.

This second edition is marked by major changes and additions which reflect the considerable progress in the design and application of centrifugal pumps since publication of the first edition. Major changes and additions include a new chapter on water-hammer problems, new material on centrifugal-jet systems, and the introduction of a thermal cavitation criterion to correlate pump behavior when pumping liquids of different physical and thermal properties. A new viscosity correction chart is introduced in Chapter 14 covering a wider range of pump types. New charts are given in Chapter 9 relating to impeller design for any discharge angle, and a procedure is established to select the casing design elements to suit impellers.

Dr. Stepanoff holds numerous patents in the centrifugal pump field and has been a development engineer for the Ingersoll-Rand Company since 1940.

RESEARCH

Advisory and Coordinating Mechanisms for Federal Research and Development, 1956–57. (NSF-13.) Washington, National Science Foundation, 1957. 27 pp.

This publication describes the formally established committees, panels, boards, and councils which cooperate with Federal departments and agencies in planning, coordinating, and executing programs of scientific research and development. The present compilation is essentially an elaboration of Appendix C of the National Science Foundation's 1956 report, entitled *Organization of the Federal Government for Scientific Activities*, and covers procedures not treated earlier for reasons of space. In addition, further data, somewhat more conveniently organized, are provided here on the composition and functions of many of the advisory panels and committees.

ROTATING WING AIRCRAFT

Helicopter Service for the San Francisco Bay Area. San Francisco, Bay Area Aviation Committee, San Francisco Bay Area Council, 1957. 21 pp., map, tables.

A survey disclosing the extent to which helicopter facilities are available or can be made readily available in the Bay Area.

STRUCTURES

Thermal Stresses: With Application to Airplanes, Missiles, Turbines, and Nuclear Reactors. B. E. Gatewood. New York, McGraw-Hill Book Company, Inc., 1957. $7.50.

Based on a course in thermal stresses given by the author to graduate aeronautical engineering students at the Institute of Technology, USAF, this book represents an attempt to give basic information for the task of solving problems involving temperature, thermal stresses, and material properties brought about by the advent of supersonic speeds for airplanes and missiles. The mathematical procedures used in the first eight chapters do not go beyond elementary partial differential equations. Chapter 9, which describes general procedures for solving thermal-stress equations in two dimensions, requires some knowledge of the theory of complex variables and of energy methods as used in structural analysis. Professor Gatewood, who is Research Coordinator at the Institute of Technology, USAF, has not restricted his book to the classical thermal-stress problem of finding the elastic thermal stresses for a given temperature distribution in a structure with no blocking, but touches on all phases of the structural design problem—the temperature distribution; the elastic and inelastic thermal stresses in various structures; the combined elastic and inelastic applied and thermal stresses; the allowable stresses for various material and loading conditions; the buckling, deflection, stiffness, fatigue, shock, and flutter effects of elevated temperatures.

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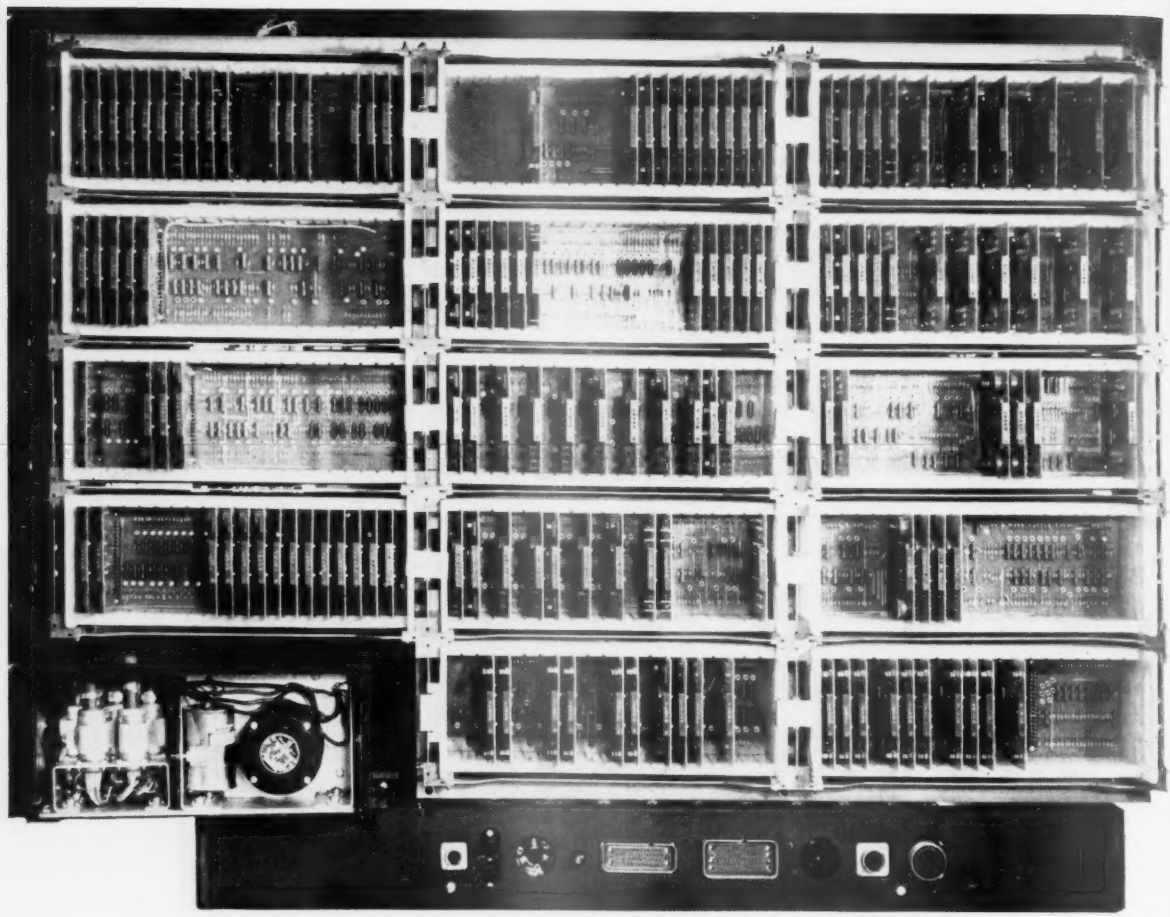

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Boral for Neutron Shielding. 4-page folder describes boral, its composition, uses, and shielding properties. *Brooks & Perkins, Inc.*, 1950 W. Fort St., Detroit 16, Mich.

"Chemloy" Bearing Material. For dry bearing applications at temperatures up to 500°F.; claimed excellent for applications subject to impact; will not permanently deform because of shock. *Crane Packing Co.*, Dept. ARN, 6400 Oakton St., Morton Grove, Ill.

Advanced Powder Metallurgy. 12-page booklet "Precision Sintered Metal Parts" describes powder metal parts. *Dixon Sintaloy Inc.*, 535 Hope St., Stamford, Conn.

"Teflon" 100-X Perfluorocarbon Resin. Approaches the outstanding heat resistance of "Teflon" tetrafluoroethylene resins but has a melt viscosity low enough to permit extrusion in standard equipment. *E. I. Du Pont de Nemours & Co.*, Wilmington, Del.

"Four Square" Silicon Iron. This new doubly oriented magnetic sheet material is easily magnetized in four directions; designed to increase the efficiency of transformers, motors, and generators. *General Electric Research Laboratory*, Schenectady, N.Y.

Stainless Steel Finishing Methods. 18-page catalog covers requirements peculiar to stainless steel finishing and how they are best met. *R. G. Haskins Co.*, 2651 W. Harrison St., Chicago 12, Ill.

"Multimet" High-Temperature Alloy. 24-page booklet describes alloy for use at high stresses up to 1,500°F. and at moderate stresses up to 2,000°F. *Haynes Stellite Co.*, Div. of Union Carbide Corp., 30-20 Thomson Ave., Long Island City 1, N.Y.

7,200-Lb. Titanium Ingots. This new ingot is 32 in. in diameter and is equivalent in size to a 13,000-lb. steel ingot; permits larger titanium forgings. *Rem-Cru Titanium, Inc.*, Midland, Pa.

New Epoxide Adhesives Bond Stainless Steel. Claimed to be the first successful adhesives for stainless steel metal-to-metal bonds and for stainless steel honeycomb sandwich constructions capable of withstanding continuous exposure to temperatures up to 500°F.; write for Special Product Report #1020. *Rubber & Asbestos Corp.*, 225 Belleville Ave., Dept. P., Bloomfield, N.J.

AIRCRAFT & MISSILE PARTS & EQUIPMENT

REL 38B Aviation Spark Plug. Follows the concept of the massive electrode design recently adopted by the USAF. *Champion Spark Plug Co.*, 900 Upton Ave., Toledo 1, Ohio.

Midget Thermocouple Glands. These units are less than $1^1/_2$ in. long by 1/2 in. hex and provide a positive seal for bare wire thermocouples from 0.005 microns to 5,000 psi. *Conax Corp.*, 2300 Walden Ave., Buffalo 25, N.Y.

Nylon Wire Clamps. 4-page folder describes a fast, lightweight way to secure wires in aircraft, missile, and electronic assemblies. *Dakota Engineering, Inc.*, 6641 Crenshaw Blvd., Los Angeles 43, Calif.

Mass Air Blower. Designed for use in systems where a constant volume of airflow is required at varying altitudes; through use of an induction motor and magnetic coupling, the speed of the fan is approximately 1/3 of the motor speed at sea level; at higher altitudes as the density of the air decreases, reducing air resistance to the blades, the speed of the fan increases. *Eastern Industries, Inc.*, Hamden, Conn.

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Aeronautical Engineering Review

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Lightweight Shutoff Valves for Fluids & Gases. These motor-operated units provide bubbletight flow control through a pressure range of 0 to 1,000 psi at temperatures from −65° to +200°F. *Hydromatics, Inc.*, 70 Okner Pkwy., Livingston, N.J.

Stainless Steel Shutoff Valve. Motor operated for cryogenic applications −320° to +160°F.; handles corrosive fluids and gases; features straight through "Flo-Ball" design. *Hydromatics, Inc.*, Cedar Grove, N.J.

"Snap-Tite" Gas Tank Closure. A simple downward snap of the lever assures a perfect seal each time the tank is opened and closed for refueling. *Moeller Mfg. Co.*, Industrial Div., Racine, Wis.

Engineering Data Folder. Handy file folder describes company's engineering, design, and manufacturing facilities. *Moynahan Bronze Co.*, Flat Rock 2, Mich.

"Nicad" Sintered Plate Nickel Cadmium Batteries. Bulletin 501A shows characteristics, construction, and discharge curves. *Nickel Cadmium Battery Corp.*, Easthampton, Mass.

Parker O-Ring Handbook 5700. 160 pages incorporate numerous illustrations, tables, charts, and other data on synthetic rubber O-ring seals. *Parker Appliance Co.*, Rubber Products Div., 17325 Euclid Ave., Cleveland 12, Ohio.

Slow-Opening Oxygen Cylinder Valve. Reduces the possibility of oxygen accidents by preventing sudden pressure surges when the oxygen system is turned on; weighs 25½ oz. *Scott Aviation Corp.*, 302 Erie St., Lancaster, N.Y.

H-10 Self-Contained Gyro Horizon. This new 8-lb. instrument provides a large, 5-in. pictorial display of the position of an aircraft in relation to the natural horizon. *Sperry Gyroscope Co.*, Div. of Sperry Rand Corp., Great Neck, N.Y.

Diaphragm TeeJet Nozzle for Airplane Spraying. A manual shutoff assembly eliminates the need for removing orifice tips and inserting blanks. *Spraying Systems Co.*, 3201 Randolph St., Bellwood, Ill.

NAS 624-644 Series High-Strength Aircraft Bolts. Technical Bulletin compares these 12-point external wrenching bolts with fatigue properties of MS 20004 Series aircraft bolts. *Standard Pressed Steel Co.*, Box 869, Jenkintown, Pa

100° Flush-Head Aircraft Screws. Feature "Torq-Set" recess which allows maximum tightening without cam-out, burred slots, or broken heads. *Standard Pressed Steel Co.*, Jenkintown, Pa.

Fiberglas-Reinforced Plastic Inserts for Aircraft Galleys. Include tray carriers, ice containers, liquid jugs, storage units of all kinds; both single-wall and double-wall (insulated) units are available. *Weber Aircraft Corp.*, 2820 Ontario St., Burbank, Calif.

Model 426-001 Missile Flight Programmer. Provides desired variable voltages versus time outputs to perform various linear and nonlinear functions in the planned flight of missiles. *Western Design & Mfg. Corp.*, Santa Barbara Airport, Goleta, Calif.

Flexible Shafts. 14-page bulletin gives basic information and data on a complete line of shafts for a wide range of remote control, power drive, and coupling applications. *S. S. White Industrial Div.*, 10 E. 40th St., New York 16, N.Y.

"Why the Silver-Zinc Storage Battery?" Bulletin describes the rigid tests carried out on silver-zinc, lead-acid, and nickel-cadmium batteries. *Yardney Electric Corp.*, 40–50 Leonard St., New York 13, N.Y.

ELECTRONIC & ELECTRICAL EQUIPMENT

Switching Transistor Power Supply. 4-page folder describes 60-watt unit regulated against both line and load variations simultaneously. *Arnold Magnetics Corp.*, 4613 W. Jefferson Blvd., Los Angeles, Calif.

Time Delay Relays & Sequence Program Switches. Offers up to six load circuits in the repeat-cycle timer and up to five load circuits in the reset-cycle unit; developed to meet all the varied requirements of sequence programming. *Automatic Timing & Controls, Inc.*, King of Prussia, Pa.

Model 11 SM 460 115-Volt, 400-Cycle High Torque-to-Inertia Servomotor. Rated for 200°C. unit temperature, continuous duty operation at stall. *Beckman/Helipot Corp.*, Newport Beach, Calif.

Size 11, 115-Volt, 400-Cycle Servomotor. Has a rotor inertia of 1.3 gm. cm.^{2} torque at stall of 0.63 oz.in. and an acceleration at stall of 34,200 rad./sec.^{2} *Beckman/Helipot Corp.*, Newport Beach, Calif.

"Tramp" Transistor Servoamplifier. 4-page brochure covers performance characteristics of the 60- and 400-cps units. *M. Ten Bosch, Inc.*, Pleasantville, N.Y.

Solderless Multilead Plug-and-Receptacle Connector. Pins and sockets are crimped to wire ends by single-stroke manual or high-speed automatic tools; speeds wiring of electronic harnesses. *Burndy Corp.*, Norwalk, Conn.

"Q" Quick-Disconnect Bulletin PR-Q. Describes this new electrical connector series adaptable for aircraft usage. *Cannon Electric Co.*, 3208 Humboldt St., Los Angeles 31, Calif.

Printed Circuit Connector for Computer Application. Claimed to be the longest precision printed circuit connector known; 2-page technical bulletin gives specifications. *DeJur-Amsco Corp.*, 45-01 Northern Blvd., Long Island City 1, N.Y.

Size 11 Motor Tachometer. Model No. SJ1HLX7-18CC delivers 0.6 volts per 1,000 r.p.m. with 19 milivolts of total null; measures 2.125 in. long *Eastern Air Devices, Inc.*, 385 Central Ave., Dover, N.H.

4CX1000A High-Current Low-Voltage Radial Beam Tetrode. Features high power gain and a plate dissipation of 1,000 watts; ceramic-metal construction. *Eitel-McCullough, Inc.*, San Bruno, Calif.

DPDT Die-Cast Switch. Provides simultaneous, one-way action on two poles; claimed to be excellent for pulsing electrical control on both pneumatic and hydraulic valves and similar installations requiring momentary one-way electrical impulses. *Electro Snap Switch & Mfg. Co.*, 4218 W. Lake St., Chicago 24, Ill.

Model AT-70 Microwave Power Attenuator. Designed for broad-band power attenuation over a range of frequencies from d.c. to 4,000 mc. *Empire Devices Products Corp.*, Amsterdam, N.Y.

"Transistor Manual." The second edition of this 112-page booklet contains basic information on transistors and their use in electronic circuits. *General Electric Co.*, Semiconductor Products Dept., Syracuse, N.Y.

DC-103 Binary Time Code Generator. Designed to produce a serial output of one synchronizing pulse followed by eight bits of binary coded d.c. timing signals per second. *G. M. Giannini & Co., Inc.*, 918 E. Green St., Pasadena 1, Calif.

Model 293M1725 High-Temperature Selenium Rectifier. Weighs only 5.5 lbs. and measures 5 by 6 by 6 in.; 6-phase, full-wave unit with a rating of 100 amp., 28 volts; operates at 125°C. *International Telephone & Telegraph Corp.*, Components Div., 100 Kingsland Rd., Clifton, N.J.

No. 1259 Rotary Selector Switch. This 16-position, single-pole unit is designed to have a minimum operating life of 10,000 double cycles at rated electrical load with a torque of 11 in.lbs. maximum. *Janco Corp.*, 3111 Winona Ave., Burbank, Calif.

Ceramic Relay for Missile & Aircraft Applications. Contacts are in a vacuum surrounded by a ceramic enclosure; will operate satisfactorily under severe environmental conditions without contact chatter. *Jennings Radio Mfg. Corp.*, P.O. Box 1278, San Jose, Calif.

Miniature, Heavy-Duty, Four-Throw Toggle Switch. Built for extreme reliability to eliminate the need for rewiring and replacements in devices requiring unfailing service. Capacity is 20 amp. inductive at 28 VDC for 10,000 cycles; size 1.8 cu.in.; weighs 2 oz. *Mason Electric Corp.*, 3839 Verdugo Rd., Los Angeles, Calif.

Pickoff & Sector Potentiometers. For aircraft and missile control systems; bulletin #415 gives specifications and outline drawings. *Norden-Ketay Corp.*, Commerce Rd., Stamford, Conn.

High Output Voltage, Fluid Damped, Linear Accelerometer. Internal design essentially eliminates the effects of crosstolls reducing hysteresis to a negligible factor. *Physical Measurements Corp.*, 1650 19th St., Santa Monica, Calif.

Miniature Precision Wirewound Resistors. Two models are available for printed circuits; both are fixed, noninductively wirewound types sealed in epoxy resin and suitable for operation in ambients up to 125°C. *Shallcross Mfg. Co.*, Collingdale, Pa.

"Klixon" Rotary Switch. Has simultaneity within $1\frac{1}{2}°$ rotation; designed for aircraft landing gear, engine controls, missile launchers, etc. *Spencer Thermostat Div.*, Metals & Controls Corp., Attleboro, Mass.

Type SN-2146B Audio Beam Power Amplifier. Makes use of stacked ceramic construction; is capable of 4.5 watts power output under class A conditions. *Sylvania Electric Products Inc.*, 1740 Broadway, New York 19, N.Y.

Model 198 Transistor Amplifier. Claimed to be the only commercially available transistor amplifier with a 1% closed-loop gain stability from −60° to +125°C. *Taber Instrument Corp.*, Sect. 40, N. Tonawanda, N.Y.

Series 17,000 High-Power Coaxial Switch. For use where high power is required for frequencies up to 5,000 MC; weighs $4\frac{1}{2}$ lbs. *Transco Products, Inc.*, 12210 Nebraska Ave., Los Angeles 25, Calif.

Transfer Coaxial Switch. Permits crossover and/or double-pole transfer switching of coaxial cable. *Transco Products, Inc.*, 12210 Nebraska Ave., Los Angeles 25, Calif.

Silicon Transistors. Bulletin No. TE1353 gives complete technical data on company's line. *Transitron Electronic Corp.*, Wakefield, Mass.

Model Wpl-5/8 Precision Potentiometer. $1\frac{5}{8}$ in. size for linear and nonlinear applications; resistance values from 1/2 to 500,000 ohms with standard linearity of 0.5% are available in this new model. *Waters Mfg., Inc.*, Boston Post Rd., Wayland, Mass.

DRAFTING ROOM, PRODUCTION, & MISC. EQUIPMENT

Portable Nibbler Cuts Titanium. Model HN cuts up to 55 in. per min. without distortion on either side of the cut. *Fenway Machine Co.*, Willow Grove, Pa.

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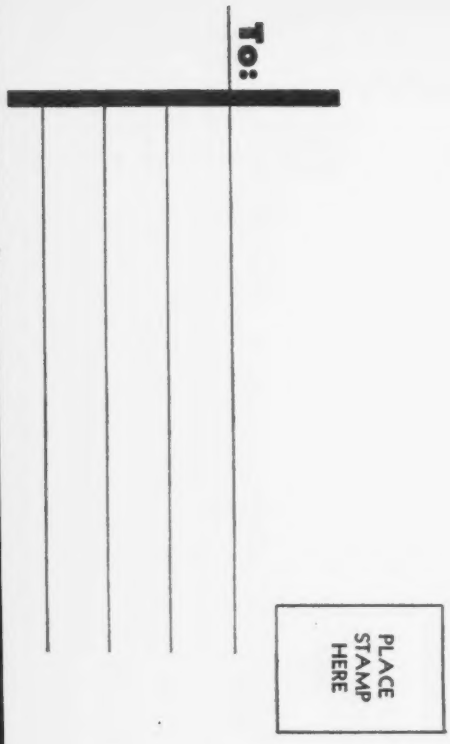
Model #CV 10-12 Jet Blast Fence. Designed to deflect jet blast streams upward at a vertical angle allowing safe jet aircraft parking on crowded airports. *Food Machinery & Chemical Corp.*, John Bean Div., 1115 Coleman St., San Jose 4, Calif.



RESEARCH & TEST EQUIPMENT

Environmental Testing Laboratory. Brochure describes facilities and equipment used to perform such tests as vibration, high and low temperature, humidity, altitude, acceleration, etc. *Associated Testing Laboratories, Inc.*, 414 Clinton Rd., Caldwell, N.J.

Type 6010 Precision Delay Generator. 4-page brochure describes unit for applications requiring accurate, variable, time interval pulses. *Burroughs Corp.*, Electronic Instruments Div., 1209 Vine St., Philadelphia 7, Pa.

Portable Mach Calibrator for Pitot Static Instruments. May be used on flight lines to check and test all aircraft instruments and systems functioning by either pitot or static pressure; features a self-contained motor and pump system and a regulator system which permits simulation of sea-level conditions regardless of airport altitude. *Burton Mfg. Co.*, Santa Monica, Calif.

Model 251 Analog Computer Multiplier. This unit generates a voltage proportional to the instantaneous product of two arbitrary input voltages from d.c. to 5 kc. with less than 5 μsec. delay. *Chadwick-Helmuth Co.*, 472 E. Duarte Rd., Monrovia, Calif.

Model 21A Pushbutton Test Oscillator. Features all-transistor circuitry, printed wiring, and self-contained power supply; provides eight preset frequencies (user-specified) within the range of 15 cycles to 150 kc. at a source impedance of less than 0.5 ohm. *Consolidated Electrodynamics Corp.*, 325 N. Altadena Dr., Pasadena, Calif.

Type 4-317 High Temperature Pressure Transducer. Permits accurate measurements of pressures up to 5,000 psig; can be operated continuously at 5 volts maximum input over a temperature range of −350° to +600°F. with allowable transients up to +750°F. *Consolidated Electrodynamics Corp.*, 300 N. Sierra Madre Villa, Pasadena, Calif.

Static Test Deflection Sensor. For aircraft, missile, and general static structural test applications; unit measures deflection over ±10 and ±48 in. with an accuracy of ±0.5%. *Frank R. Cook Co.*, 36 S. Santa Fe Dr., Denver 23, Colo.

P900 Reluctance-Type Pressure Transducer with D.C. Output. Suited for air-borne test stand and laboratory applications. *Datran Electronics*, 3615 Aviation Blvd., Manhattan Beach, Calif.

Automatic Micrometer for Compressible Material. This digital read-out unit can measure fragile nonconductors to within twenty millionths of an inch. *J. W. Dice Co.*, Englewood, N.J.

Model DI-3 Test Chamber. Covers a range of temperatures from −100° to ±300°F.; features low mass microhm heating unit and dry ice cooling with by-pass damper for economical operation; dimensions are 18 by 18 by 18 in. *Environmental Equipment Co.*, 369 Linden St., Brooklyn 27, N.Y.

Model 1635 Universal Vibrograph. A portable mechanical instrument for measuring and recording vibrations and accelerations on airplanes, helicopters, etc.; weighs 27 lbs. *Epic, Inc.*, 154 Nassau St., New York 38, N.Y.

Model 12000-A Lightweight, Mobile Jet-Engine Run-Up & Test System. Capable of conducting complete engine run-up tests on all jet engines without the need for permanent concrete and steel structures. *The Essig Co*, 4063 Radford Ave., N. Hollywood, Calif.

Model 170 Portable Force Calibrator. For calibrating existing weight, force, and thrust measuring systems; weighs 40 lbs.; has direct digital readout. *Gilmore Industries, Inc.*, 5713 Euclid Ave., Dept. 5030, Cleveland 3, Ohio.

Altitude Temperature Test Chamber. Nested altitude chamber lifts out to provide independent high-low temperature and altitude test units. *Mantec, Inc.*, 126 Maryland St., El Segundo, Calif.

"Parabar" Test Unit Provides Pressures to 30,000 Atm. This new research tool permits determination of compressibility, polymorphic transition, electrical resistance, and other physical properties of solids and liquids. *Nucor Research, Inc.*, 2421 Wolcott Ave., Ferndale 20, Mich.

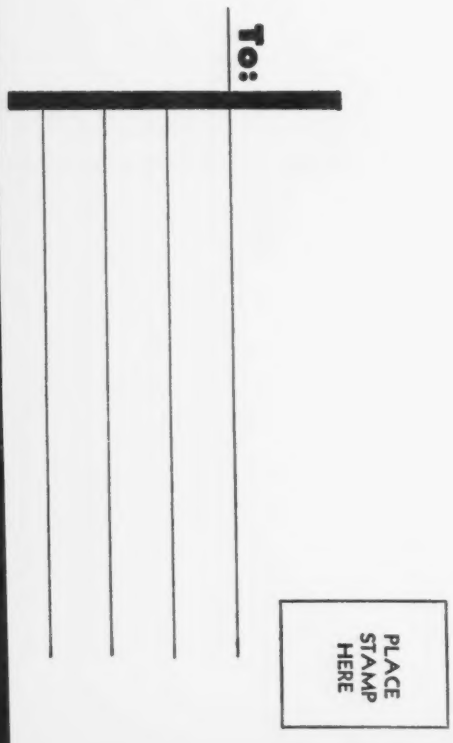
"Dynograph" Direct Writing Oscillograph Recorder. Type 503 is designed for applications requiring more than eight channels of information on one recording chart; up to 19 recording channels are available in this unit. *Offner Electronics Inc.*, 5320 N. Kedzie Ave., Chicago 25, Ill.

Missile Weighing System. For determining center of gravity of missiles and similar objects; employs two load cells feeding into a digital reading weight indicator. *Performance Measurements Co.*, 15301 W. McNichols Rd., Detroit 35, Mich.

Program Scanner. This all-electronic unit converts a curve drawn on graph paper into a voltage to be used to program radiant heat, test load, and other control, programing, or computing applications. *Spar Engineering & Development, Inc.*, Paxson & South Aves., Wyncote, Pa.

Electrical Vacuum Gages. For continuous and accurate measurement of very low absolute pressure; models are available in three pressure ranges—1 to 100 microns, 1 to 1,000 microns, and 1 to 20,000 microns. *F. J. Stokes Corp.*, 5500 Tabor Rd., Philadelphia 20, Pa.

Oscilloscope Shadow-Screen Intensifies Image in Bright Light. This new device is a thin sheet which fits directly in front of the scope face blocking off ambient light that blurs the cathode ray tube image. *Van-Dee Products*, 300 Ocean Ave., Laguna Beach, Calif.



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"FORCES OF NATURE," another in a collection of paintings by Simpson-Middleman, two talented artists who find in the natural sciences the subject matter for their contemporary expressions. Courtesy John Heiler Gallery, Inc.

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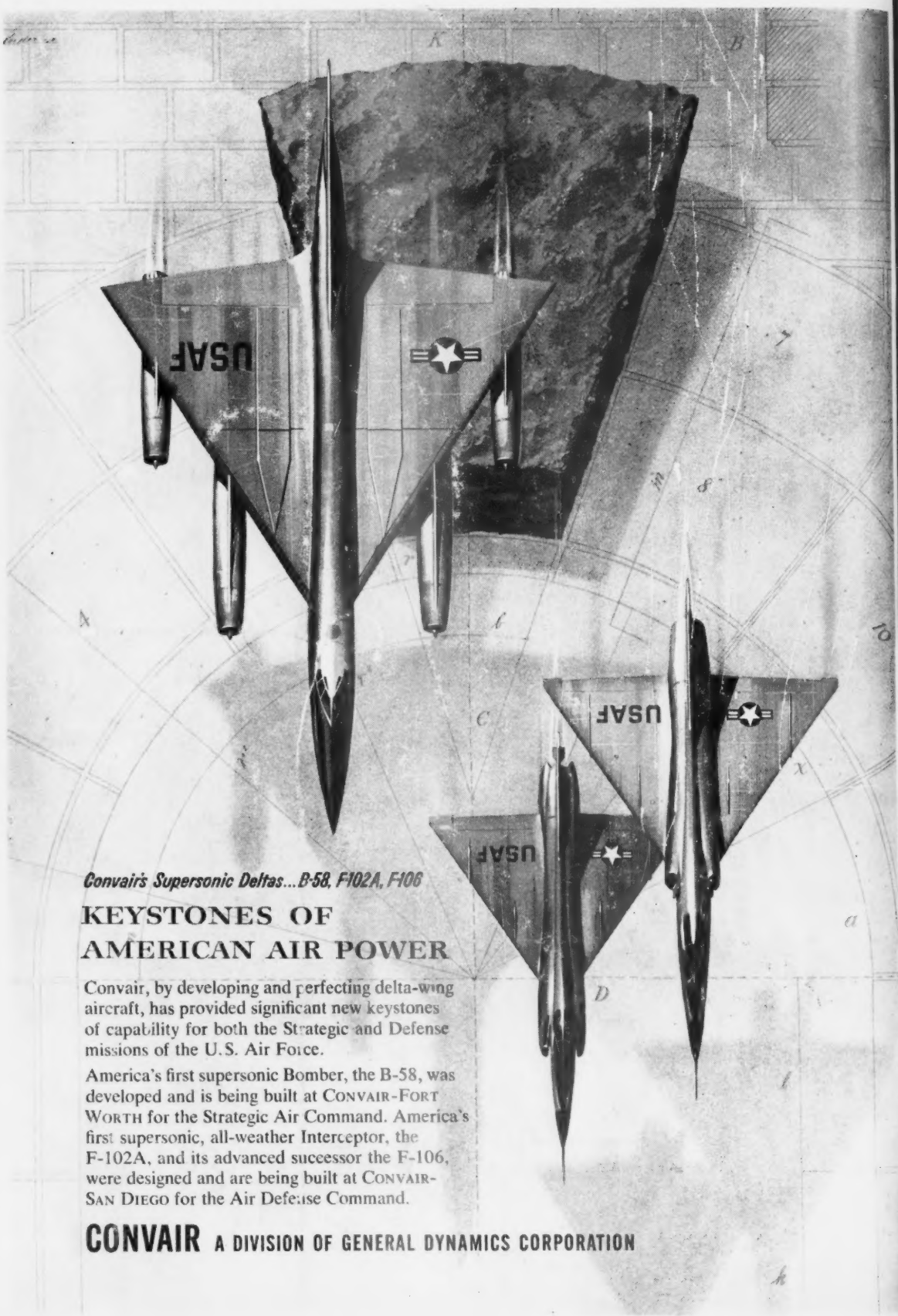
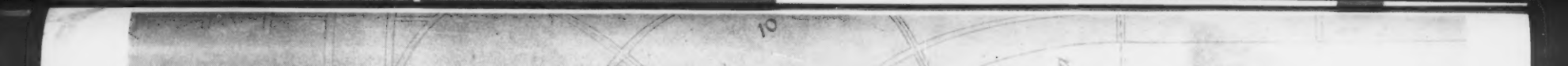


Convair's Supersonic Deltas...B-58, F102A, F106

KEYSTONES OF AMERICAN AIR POWER

Convair, by developing and perfecting delta-wing aircraft, has provided significant new keystones of capability for both the Strategic and Defense missions of the U.S. Air Force.

America's first supersonic Bomber, the B-58, was developed and is being built at CONVAIR-FORT WORTH for the Strategic Air Command. America's first supersonic, all-weather Interceptor, the F-102A, and its advanced successor the F-106, were designed and are being built at CONVAIR-SAN DIEGO for the Air Defense Command.

CONVAIR A DIVISION OF GENERAL DYNAMICS CORPORATION